Hindawi
International Journal of Agronomy
Volume 2019, Article ID 3926765, 8 pages
https://doi.org/10.1155/2019/3926765

Research Article

Evaluation of Yield, Reaction to Diseases, and Grain Physical Attributes of Some Introduced Rice Hybrids in Ghana

Samuel Oppong Abebrese,[1] **Alex Yeboah**,[1] **Wilson Dogbe**,[1] **Paul Kofi Ayirebi Dartey**,[2] **Richard Akromah**,[3] **Vernon Edward Gracen**,[4] **Samuel Kwame Offei**,[4] **and Eric Yirenkyi Danquah**[4]

[1]*CSIR-Savanna Agricultural Research Institute, P.O. Box TL 52, Tamale, Ghana*
[2]*CSIR-Crops Research Institute, P. O. Box 3785, Kumasi, Ghana*
[3]*Department of Crop and Soil Sciences, KNUST, Kumasi, Ghana*
[4]*West Africa Centre for Crop Improvement, University of Ghana, Legon, Ghana*

Correspondence should be addressed to Samuel Oppong Abebrese; sam555oppa@yahoo.com

Received 25 October 2018; Revised 13 January 2019; Accepted 12 February 2019; Published 13 March 2019

Academic Editor: Maria Serrano

Hybrid rice technology is one of the promising, sustainable, and proven technologies for increasing rice production and productivity with a yield advantage of 15–30% over modern inbred varieties. The potential of hybrid rice has so far not been exploited in Ghana. This study was undertaken to evaluate the yield potential, reaction to diseases, and physical grain attributes of some introduced hybrids. The trials were laid out in a randomized complete block design (RCBD) with three replicates across three locations. Data were taken on grain yield, yield components, reaction to diseases, and grain physical characteristics. Four promising hybrids (SWARNA 2, ARGH 1501, ARGH 1502, and ARGH 1503) with a mean yield advantage of 15–20.8% over the best inbred check "AgraRice" were identified. With few exceptions, the hybrids were broadly adapted and had adequate resistance to blast and bacterial leaf blight. Most of the test hybrids had long slender grains which make them acceptable to the Ghanaian market but lacked aroma.

1. Introduction

Rice (*Oryza sativa* L.) is the second most important cereal in Ghana after maize [1]. Local production is around 40% of national consumption resulting in the importation of about 680 000 tons of rice, which cost the country over 500 million USD annually [2, 3]. With population growth, urbanization, and shifting consumer preferences, demand of rice is expected to keep increasing [4, 5]. Ghana is endowed with suitable land resources to be self-sufficient in rice production [1]. Recent data show that rice production has been increasing at 7.5% annually since 2009, but most of this increase (6%) comes from land area expansion, and only 1.5% comes from productivity improvements [3]. There is the need to exploit all available technologies to increase local production and productivity. One technology for genetically improving the yield potential of rice is through the use of hybrid varieties [5–8]. The potential of hybrid rice has so far not been exploited in Ghana. Commercialization of hybrid rice in Ghana has begun by interested private seed companies introducing and testing hybrids mostly from Asia.

Hybrid rice is a promising and sustainable technology for increasing rice production and productivity [9–11]. It has been proven practically that hybrid varieties could out-yield their inbred counterparts grown under similar conditions by 15–20% [10, 12]. The superiority of hybrids over their inbred counterparts may be expressed in grain yield, vigor, panicle size, number of spikelets, and number of productive tillers [10–12]. Since hybrid rice seeds cannot be used for replanting due to the resulting segregation in most of the valuable agronomic traits, farmers are forced to buy fresh seeds for each season's planting [12]. This presents an opportunity for private seed companies and encourages private-sector involvement in seed production, research, and development [13]. Since the hybrid varieties yield 15–20% more than the pure line varieties, farmers prefer hybrid seeds if the price is economically beneficial and seeds are reliably available [14]. Hybrid rice is extensively commercialized in China where over 50% of the total land area for rice is planted to hybrids [15, 16]. Other Asian countries like India, Philippines, Thailand, Vietnam, Indonesia, and Bangladesh have also commercialized hybrid rice [12]. It is also effectively utilized in Brazil and the USA [12]. In Africa, Egypt is the only country which has successfully developed a hybrid rice breeding program that produces local rice hybrids on a commercial scale [13]. AfricaRice (Africa Rice Centre) initiated a hybrid breeding program in 2010 to develop superior hybrids for sub-Saharan African countries [13, 17].

Successful adoption of hybrid rice by farmers depends highly on the availability of superior hybrids which combine higher yields with farmer preferred traits [12]. Rice blast (caused by *Pyricularia oryzae* (anamorph) and *Magnaporthe oryzae* (teleomorph)), bacterial leaf blight (BLB) (caused by *Xanthomonas oryzae*), and rice yellow mottled virus (RYMV) are the three most important rice diseases in Ghana [2, 18]. A yield loss of 3.5–77% has been reported for the rice blast disease [19]. RYMV disease, although sporadic, can cause complete yield loss to susceptible varieties [2]. Varietal resistance is the recommended management strategy for these three diseases. Released varieties are therefore required to possess adequate levels of resistance to survive these diseases. Rice grain quality is a major determinant of rice varietal adoption in Ghana [2, 20]. The Ghanaian market has high preference for intermediate amylose, long slender aromatic rice grains, with these characters accounting for over 40% increase in price quotations [2, 21, 22]. Locally developed rice varieties are expected to possess these grain quality attributes in order to be able to compete with the imported brands in the market.

Before the release of a variety, many genotypes are evaluated for performance capabilities relative to checks under various environmental conditions over several seasons and years to enable prediction of future performance in farmers' fields [23, 24]. Yield stability of the test varieties is also important in such trials [24, 25]. Thorough genotype by environmental interaction (G × E) and stability analyses in multienvironment trials (MET) help us to select varieties that are adapted to specific environments and those with broad adaptation across a set of environments [25, 26]. Many statistical methods are available for assessing the stability of genotypes across environments [24–26]. Among them, the genotype main effect plus genotype by environment interaction (GGE) biplot is recognized as the most innovative methodology in biplot graphic analysis which is applied in plant breeding [25, 27, 28]. GGE biplot produces a graphical display of results that facilitates a better understanding of complex genotype by environment interaction in multienvironment trials of breeding and agronomic experiments [26, 29]. It complements the results of the analysis of variance (ANOVA) in that, after the ANOVA had shown significant mean squares for genotype by environmental interaction (GEI), GGE biplot graphically analyses the nature of the interactions [24, 29]. However, the total variation of a phenotype could be partitioned into the genotype (G) effect, environment (E) effect, and genotype by environment interaction (GEI) effect, and the GGE biplot model considers only G and GEI as relevant to cultivar evaluation and the two factors are considered simultaneously, removing the environment (E) effect [29]. This is because the concept of crop performance and stability, as considered by crop scientists when selecting superior genotypes, is centered on G and GEI effects only [24, 25, 29]. The "mean versus stability" view of GGE biplot ranks entries according to their performance and stability across environments [29, 30].

This study assessed the yield potential and stability of some introduced rice hybrids across locations, their reaction to local biotic stresses, and physical grain quality attributes.

2. Materials and Methods

2.1. Plant Materials. A total of fourteen hybrids were assembled from interested private seed companies and agencies: Wienco Ghana, Advanta Seeds Company, and IFDC-Agricultural Technology Transfer Project (IFDC-ATTP) in 2014 and 2015. Eight of these hybrids were introduced and evaluated in 2014, whilst the remaining six were introduced in 2015. The performances of these hybrids were benchmarked to the two local inbred checks Jasmine 85 and AgraRice (Table 1).

2.2. Experimental Locations. The trials were conducted at Nyankpala (09°24′17.8″N, 000°57′57.0″W, 143 m), Golinga (09°21′06.0″N, 000°57′01.0″W, 139 m), and Navrongo (10°36′4.89″N, 1°15′9.47″W, 195 m) in 2014. The 2015 locations were Golinga, Navrongo, and Nobewam (06°37′23.8″N, 001°07′03.8″W, 193 m). The Nyankpala and Golinga sites were within the Guinea Savanna agro-ecological zone, the Navrongo site was within the Sudan Savanna zone, and Nobewam within the semideciduous rainforest. Golinga, Navrongo, and Nobewam were irrigated ecologies, whereas Nyankpala site was rainfed lowland ecology. These locations are considered as blast disease hot spots and were selected as key screening sites from the previous study [19].

2.3. Experimental Design and Trial Management. The trials were laid out in a randomized complete block design (RCBD) with 3 replicates across locations in a plot size of $10\,m^2$. Seeds were pregerminated, nursed, and transplanted one seedling per hill after 21 days in a spacing of 20 cm within and between rows. Seeds were directly sown and thinned to one seedling per hill at Nyankpala (the rainfed lowland ecology). The recommended fertilizer rate of 90 : 60 : 60 kg NPK/ha was applied in two splits. Basal application of 60 : 60 : 60 was applied a week after transplanting at the irrigated sites and two weeks after germination at Nyankpala (the rainfed ecology). Top dressing with 30 kg nitrogen in the form of urea was done at the booting stage. Weeds were

Table 1: List of hybrids and inbred checks used for the study.

Variety/entry	Status	Source	Year evaluated
INDAM 200-002	Hybrid	IFDC-ATTP	2014
INDAM 100-002	Hybrid	IFDC-ATTP	2014
INDAM 100-001	Hybrid	IFDC-ATTP	2014
GR-2	Hybrid	IFDC-ATTP	2014
GR-1	Hybrid	IFDC-ATTP	2014
GR-3	Hybrid	IFDC-ATTP	2014
S71680676	Hybrid	Wienco Ghana	2014 and 2015
S72180002	Hybrid	Wienco Ghana	2014
PAC 832	Hybrid	Advanta Seeds Co.	2015
PAC 801	Hybrid	Advanta Seeds Co.	2015
SWARNA 2	Hybrid	Advanta Seeds Co.	2015
ARGH 1501	Hybrid	Advanta Seeds Co.	2015
ARGH 1502	Hybrid	Advanta Seeds Co.	2015
ARGH 1503	Hybrid	Advanta Seeds Co.	2015
Jasmine 85	Inbred check	CSIR-SARI	2014 and 2015
AgraRice	Inbred check	CSIR-SARI	2014 and 2015

controlled manually whenever necessary. Standard agronomic practices were followed as recommended.

2.4. Data Collection. Data were collected on grain yield per plot, number of tillers per plant, number of panicles per plant, number of filled grains per panicle, days to 50% flowering, plant height at maturity, thousand grain weight, presence of aroma (fragrance), disease score for leaf blast, and bacterial leaf blight (BLB); grain length, grain width, and grain shape (length/width ratio) all were based on International Rice Research Institute's Standard Evaluation System for rice (IRRI SES) [31]. Visual scores of leaf blast incidence and severity were recorded using the IRRI's SES scale of 0–9 based on percent diseased leaf area (Table 2). Visual scores of BLB incidence and severity were also recorded using IRRI SES scale of 0–9 based on percent dead leaf area (Table 3). Based on the average disease score, genotypes were categorized into resistant (0–3), moderately resistant (4–6), and susceptible (7–9). To detect the presence of aroma, samples of decorticated rice grains were put into an eppendorf tube. 2-Acetyl-1-pyrroline (AcPy), the main component of aroma in rice, was vaporized by adding 10 ml of 1.7% solution of potassium hydroxide (KOH) and capped for 10 minutes. The levels of expression of aroma were compared to those of Jasmine 85, a released aromatic variety as control [31].

2.5. Data Analysis. Analysis of variance (ANOVA) for grain yield, yield components, and disease scores was carried separately for each location using GenStat statistical package (12th edition) [32]. Combined ANOVA across locations was also conducted. Least significant difference (LSD 0.5) was used for mean comparisons and separation. Stability of hybrids and checks was assessed with GGE biplot analysis performed in R statistical package (GGEBiplotGUI) as in [30].

Table 2: Descriptive key for recording leaf blast disease severity.

Score	Description of symptoms
0	No lesions observed
1	Small brown specks of pinhead size or long brown specks without sporulating centre
2	Small roundish to slightly elongated, necrotic grey spots, about 1-2 mm in diameter with a distinct brown margin
3	Lesion type is the same as in scale 2, but a significant number of lesions are on the upper leaves
4	Typical susceptible blast lesions, 3 mm or longer, infecting less than 4% of the leaf area
5	Typical blast lesions infecting 4–10% of the leaf area
6	Typical blast lesions infecting 11–25% of the leaf area
7	Typical blast lesions infecting 26–50% of the leaf area
8	Typical blast lesions infecting 51–75% of the leaf area and many leaves are dead
9	More than 75% leaf area affected

Table 3: Descriptive key for recording BLB severity.

Scale	% dead leaf area
0	No incidence
1	1–5
3	6–12
5	13–25
7	26–50
9	>50

3. Results

When comparing all locations per year, the effect of factors was significant ($P < 0.05$) for six traits excluding grain yield in 2014. Significant difference was observed for all seven traits including grain yield in 2015 (Table 4). Genotype by location interaction was significant for number of tillers, days to 50% flowering, days to maturity, and grain yield in 2014. In 2015, significant genotype by location interaction was observed for plant height, days to 50% flowering, days to maturity, thousand grain weight, and grain yield (Table 4).

The mean yield (across locations) of hybrids ranged from 4.15 t/ha to 6.24 t/ha in 2014. The highest yielding hybrid (INDAM 200-022) recorded a yield advantage of 12.43% over the best inbred check (AgraRice, 5.55 t/ha). The yield of the hybrids was not statically different ($P < 0.05$) from the inbred checks in 2014 (Table 5). SWARNA 2 and PAC 832 yielded significantly higher ($P < 0.05$) than the inbred checks in 2015 (Table 6). The mean yield of the hybrids ranged from 7.91 t/ha to 9.57 t/ha in 2015. The highest yielding hybrid in 2015 (SWARNA 2) recorded a mean yield advantage of 20.8% over the best inbred check (AgraRice, 7.92 t/ha) (Table 6).

With the exception of INDAM 100-001 and ARGH 1503 which were taller, the test hybrids generally had similar heights as the inbred checks. The test hybrids matured between 113 and 120 days. With the exception of S71680676, S72180002, and INDAM 200-022, all hybrids had a grain length width ratio greater than three ($L/W > 3.0$) and were

Table 4: Combined ANOVA mean squares for seven traits evaluated on hybrids and checks across locations in 2014 and 2015.

Source	df	^{a}NT	^{b}PH	^{c}50% FL	^{d}DM	^{e}PP	^{f}1000 Gwt	^{g}Gyield
2014								
Rep	2	8.82	155.56	27.23	6.74	4.75	7.12	11.95
Geno	9	42.82***	814.89**	186.49***	101.25***	36.80***	129.05***	3.19^{ns}
Loc	2	47.170***	896.06**	4251.433***	34.411***	64.288***	37.979***	4.06^{ns}
G * L	18	9.31***	35.89^{ns}	23.17***	38.09***	6.20^{ns}	4.47^{ns}	3.88*
Residual	58	3.91	36.59	7.89	2.76	4.22	5.48	1.92
Total	89							
2015								
Rep	2	8.41	57.26	1.83	0.42	0.42	0.35	0.66
Geno	8	23.55*	234.68***	126.22***	50.67***	23.65*	6.38***	3.34***
Loc	2	341.82***	9813.27***	359.57***	1451.66***	20.62^{ns}	67.60***	247.22***
G * L	16	11.44^{ns}	190.87***	15.22***	14.11**	7.38^{ns}	6.38***	2.26***
Residual	52	9.88	42.77	3.34	5.67	3.79	0.45	0.76
Total	80							

*,**,***Significant at $P < 0.05$, $P < 0.01$, and $P < 0.001$, respectively; df = degree of freedom, ns = not significant, [a]number of tillers; [b]plant height; [c]days to 50% flowering; [d]days to maturity; [e]panicles per plant; [f]1000 grain weight; [g]grain yield.

Table 5: Yield (t/ha) of hybrids and checks across locations in 2014.

Variety	Golinga	Navrongo	Nyankpala	Mean across locations	Yield advantage over AgraRice (%)
AgraRice	5.69	5.50	5.47	5.55	
Jasmine 85	5.07	6.20	4.29	5.19	−6.5
GR-1	5.58	5.06	6.55	5.73	3.2
GR-2	5.60	5.63	4.43	5.22	−5.9
GR-3	5.61	6.76	5.98	6.12	10.2
INDAM 200-022	6.02	1.48*	6.45	6.24	12.4
INDAM 100-012	5.69	3.24	3.53	4.15	−25.2
INDAM 100-001	5.85	6.11	4.77	5.58	0.5
S71680676	6.48	5.66	5.55	5.90	6.2
S72180002	6.42	5.66	4.98	5.69	2.5
Mean	5.80	5.13	5.20		
SD	0.41	1.59	0.98		
LSD (0.05)	ns	ns	ns		

*Destroyed by pest (excluded from mean calculation); ns = not significant; SD = standard deviation; LSD = least significant difference.

Table 6: Yield (t/ha) of hybrids and checks across locations in 2015.

Variety	Golinga	Nobewam	Navrongo	Mean across locations	Yield advantage over AgraRice (%)
AgraRice	7.24	6.15	10.35	7.92	
Jasmine 85	6.94	6.87	9.92	7.91	−0.2
ARGH 1501	8.03	6.28	13.18	9.16	15.7
ARGH 1502	8.05	6.08	13.24	9.12	15.2
ARGH 1503	7.44	6.35	13.65	9.15	15.5
PAC 801	7.27	6.70	11.04	8.33	5.2
PAC 832	8.76	6.28	12.72	9.25	16.8
S71680676	7.50	6.08	12.28	8.62	8.8
SWARNA 2	9.40	6.21	13.10	9.57	20.8
Mean	7.85	6.33	12.16		
SD	0.81	0.26	1.38		
LSD (0.05)	1.20	ns	1.89		

ns = not significant; SD = standard deviation; LSD = least significant difference.

classified as slender. Blast and BLB incidence was confirmed by the presence of the disease symptoms on the inbred check (Jasmine 85) which is known to have some moderate resistance. With the exception of GR-1, INDAM 200-022, and ARGH 1501 which scored 5. 0, 5.0, and 4.5, respectively (moderately resistance), for bacterial leaf blight, the scores of the remaining hybrids to blast and bacterial leaf blight were similar to the inbred checks (resistance). Whilst aroma was detected in the inbred checks, none of the test hybrids was found to be aromatic (Table 7).

The first two axes (Axis 1 and Axis 2) obtained by singular-value decomposition (SVD) of the centered data explained 95.63% of the total variation attributable to genotypes and genotype by environment interaction in 2014 (Figure 1). That of 2015 was 98.2% (Figure 2). The perpendicular double-headed arrows indicated the mean genotype

Table 7: Yield components, reaction to diseases, and grain quality attributes of hybrids and checks in 2014 and 2015.

Variety	[a]NTP	[b]PH (cm)	[c]DM	[d]NP	[e]NFG	[f]1000 GT (g)	[g]LB	[h]BLB	[i]GL (mm)	[j]GW (mm)	[k]L/W	Aroma
2015												
AgraRice	10.7	106.3	120	7.3	146.8	28.8	1.0	3.0	7.0	2.4	2.8	Present
Jasmine 85	13.6	99.8	116	9.5	125.3	27.8	1.0	3.0	7.1	2.3	3.1	Present
GR-1	10.1	92.2	113	7.3	64.0	28.2	1.0	5.0	7.1	2.3	3.1	Absent
GR-2	11.0	98.4	116	7.5	88.3	28.6	1.5	3.0	7.0	2.3	3.1	Absent
GR-3	9.0	105.5	114	6.4	148.0	31.9	1.0	3.0	7.6	2.8	2.6	Absent
S71680676	12.7	99.9	122	10.5	137.5	24.7	1.1	0.0	6.6	2.2	2.9	Absent
S72180002	10.9	104.1	115	7.7	146.3	26.2	1.0	3.0	7.2	2.1	3.4	Absent
INDAM 100-001	12.4	126.3	118	10.3	95.0	23.3	1.0	0.0	7.7	1.9	4.1	Absent
INDAM 100-012	11.3	109.1	120	9.7	116.0	24.7	1.3	1.0	8.0	1.8	4.2	Absent
INDAM 200-022	8.5	112.2	114	8.4	124.0	26.2	1.0	5.0	6.5	2.5	2.6	Absent
Mean	11.0	105.4	116.8	8.5	119.1	27.0	1.1	2.6	7.2	2.3	3.2	—
SD	1.6	9.3	3.0	1.4	28.5	2.5	0.2	1.8	0.5	0.3	0.6	—
LSD (0.05)	2.4	8.8	3	3.0	45.7	2.1	0.1	1.1	0.3	0.2	0.4	—
2015												
AgraRice	11.2	122.8	120	9.2	123.7	26.5	1.0	0.5	7.0	2.3	3.0	Present
Jasmine 85	13.3	114.2	118	11.2	209.7	23.5	3.0	2.0	7.1	2.2	3.2	Present
ARGH 1501	18.4	107.5	115	16.2	238.7	22.5	2.0	4.5	6.5	2.0	3.3	Absent
ARGH 1502	15.2	121.7	120	12.3	236.0	22.5	1.5	0.0	7.1	2.1	3.4	Absent
ARGH 1503	18.0	132.2	116	12.9	305.0	20.5	1.5	3.0	6.2	2.2	2.9	Absent
PAC 801	15.7	122.2	116	14.0	118.1	19.0	1.5	2.0	7.2	2.1	3.4	Absent
PAC 832	15.6	120.9	120	11.5	198.7	26.5	1.0	0.8	7.2	2.3	3.2	Absent
S71680676	14.3	120.9	118	10.7	266.7	23.5	0.8	0.8	6.7	2.3	2.9	Absent
SWARNA 2	16.0	124.5	120	12.0	230.7	23.0	0.5	0.3	6.7	2.2	3.0	Absent
Mean	15.3	120.8	118.1	12.2	214.1	23.1	1.4	1.5	6.9	2.2	3.1	—
SD	2.2	6.8	2.0	2.0	61.3	2.4	0.7	1.5	0.6	0.1	0.2	—
LSD (0.05)	3.2	7.5	2.7	2.2	99.6	1.8	1.1	1.0	0.2	0.1	0.1	—

[a]Average number of tiller per plant; [b]average plant height; [c]days to maturity; [d]average number of panicles per plant; [e]number of filled grains per panicle (average); [f]average thousand grain weight; [g]mean leaf blast score, IRRI SES (0–9); [h]mean bacterial leaf blight score, IRRI SES (0–9); [i]grain length (mm); [j]grain width (mm); [k]grain length width ratio; SD = standard deviation; LSD = least significant difference.

score of the experiments. Performances of genotypes were ranked in the direction indicated by the single-headed arrow (average tester coordinate) in the ascending order of the mean genotype. Thus, GR-3 (G4) and SWARNA 2 (G9) were the highest yielding hybrids in 2014 and 2015, respectively (Figures 1 and 2). Stability of genotypes was ranked on the basis of their projection from the average tester coordinate (axis) on the average environment main effect. The greater the length of the projection of a genotype, the more unstable that genotype is. Thus, GR-3 (G4) and S71680676 (G9) were stable genotypes with yield above the mean in 2014, and those of 2015 were ARGH 1501 (G2) and ARGH 1502 (G3) (Figures 1 and 2, respectively). SWARNA 2 (G7), PAC 832 (G9), and ARGH 1503 (G4) were the less stable genotypes with yield above the mean in 2015 (Figure 2).

4. Discussion

Hybrid rice varieties exploit the phenomenon of heterosis to break the yield ceiling of their inbred counterparts to increase productivity per unit area [10, 11]. Although hybrid rice seed costs more than inbreds and cannot be used for replanting, farmers prefer hybrids if the yield advantage over the best available inbred is high [12]. Generally, a yield advantage of 15–20% has been reported for hybrid varieties over their inbred counterparts evaluated in similar conditions [12, 13]. The highest yielding hybrid in 2014 (INDAM 200-022) had a mean yield of 6.56 t/ha representing 12% yield advantage over AgraRice (the best available inbred; 5.91 t/ha) across locations. The 12% yield advantage was considered low compared to the anticipated yield advantage of 20–30% and motivated the introduction of new set of hybrids in 2015. Four hybrids (ARGH 1501, ARGH 1503, PAC 801, and SWARNA 2) with mean yield advantage range of 15–20.8% over AgraRice were identified in 2015. This yield advantage is within the range of what has been reported in Asia and some parts of Africa [12, 13]. Based on yield superiority, these hybrids could serve as startups whiles exploiting the possibility of identifying higher yielding ones through introduction and testing of more hybrids or developing locally superior ones.

Heterosis is exhibited in grain yield, yield components, and a range of agronomic, physiological, and biochemical traits in plants [10]. Increased yield of rice hybrids has been attributed to heterosis of the panicle number, spikelet number, and thousand grain weight to a lesser extent [12]. The highest yielding hybrid (SWARNA 2) yielded significantly higher than AgraRice (7.89 t/ha) with a yield advantage of 20.8% in 2015. With respect to yield components, the number of panicles per plant and number of filled grains per panicle of SWARNA 2 were significantly higher than that of AgraRice. Although the thousand grain weight of SWARNA 2 was lesser than AgraRice, its yield superiority

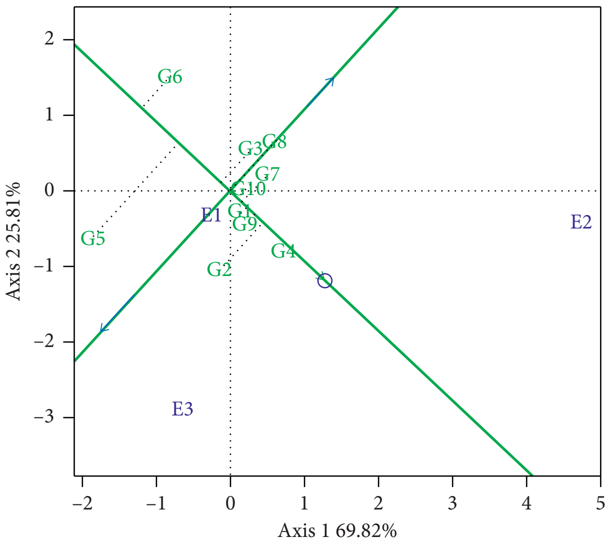


Figure 1: Mean versus stability of grain yield for hybrids and checks in 2014.

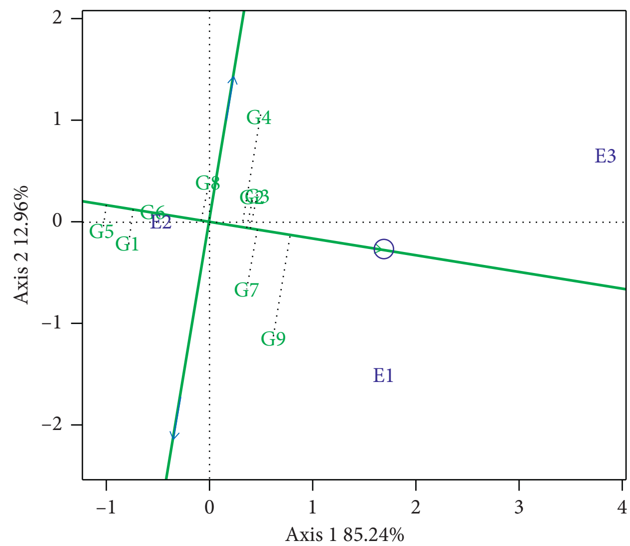


Figure 2: Mean versus stability of grain yield for hybrids and checks in 2015.

might be accounted for by the number of panicles per plant and number of filled grains per panicle.

Hybrids are generally reported to respond better to higher dose of nitrogen [12, 33, 34]. The local recommended fertilizer rate of 90 : 60 : 60 kg NPK/ha was used for the evaluations. Since the realizable field heterosis will be a major determinant for hybrid rice adoption by farmers, studying the response of these hybrids at higher doses of nitrogen (120 kg and 150 kg) is recommended. The hybrids had a medium number of days to maturity like the checks making them fit for cultivation in the tested ecologies. With the exception of INDAM 100-001 and INDAM 100-012 which were taller than the checks and are likely to be susceptible to lodging, the test hybrids had similar heights as the checks which improve their chances of farmer adoption.

The significant genotype by location (G × L) interaction for grain yield indicates that there is fluctuation in the ranks of the hybrids and checks across the test locations. Thus, one hybrid selected as the best in one location based on grain yield might not be the best hybrid in another location. This necessitated a thorough stability analysis to identify hybrids with broad adaptation across the locations and those adapted to specific locations. The test locations are really different and represent the Guinea Savanna, Sudan Savanna, and the semideciduous rainforest agroecologies. Yields in the irrigated ecology are also known to be higher than the rainfed lowland ecology. Breeders normally develop cultivars that can adapt to a wide range of environments [24, 26]. Our mean versus stability GGE biplot results revealed promising hybrids that were stable across locations. For example, GR-3, S71680676, ARGH 1501, and ARGH 1502 could be recommended for any of the defined locations as these possess stability characteristics. Although SWARNA 2, PAC 832, and ARGH 1503 had yields above the mean, they were less stable. These cultivars could be recommended for specific locations. Stability across environments is an important index of genotype performance, adaptation, and adoption by farmers since rice farmers in Ghana normally have fragmented lands and seasonal regimes. The stability of the hybrids, however, has limited interpretation since they were tested in a limited number of environments. Significant G × L interaction for some agronomic traits such as plant height and days to flowering might be due to weather, particularly, temperature difference, at the test locations. Such slight differences are often encountered for those traits even in the wet and dry seasons of same location. Thousand (1000) grain weight is one of the known stable characters of rice varieties. Significant G × L interaction for this trait could also be due to differences in soil moisture content at the locations, especially, during the grain filling stage.

Susceptibility to pest and diseases is one of the main drawbacks of hybrid rice adoption [12]. Earlier study by El-namaky and Demont [13] has indicated that hybrids from Asia are susceptible to African pest and diseases. The hybrids generally did not encounter difficulty with two (blast and BLB) of the three important rice diseases (blast, BLB, and RYMV). With the exception of a few hybrids which were particularly susceptible to blast and BLB at some locations, the hybrids had appreciable levels of resistance to the two biotic stresses. Although the hybrids were graded based on average disease score across locations, some differential scores of same hybrid at different locations was observed. This suggested differences in disease pressure at the test locations. Thus, testing reaction of genotypes to diseases should not rely only on natural field infestation but be supported with artificial (screen house) screening where a quantified disease pressure could be inoculated. Level of resistance to RYMV could not be ascertained since there was no outbreak of the disease during the evaluation period. Artificial screening of promising hybrids to RYMV is recommended before the final release as varieties. Although insect pest is often not a major problem for farmers [1], one of the test hybrids (INDAM 200-022) was totally destroyed by an unidentified pest at Navrongo in 2014. The damage which basically involved defoliation of the plant and, in severe conditions, devouring the entire shoot was typical of grasshopper and related insects damage. This draws the attention of a possible specific preference of particular hybrid variety by local insects.

Rice grain quality is an important determinant of varietal adoption and a major breeding objective in most national breeding programs [2]. Poor grain quality of hybrid varieties was a major drawback of hybrid rice adoption in Asia [12]. Grain quality is determined by appearance of whole grains (grain length, width, shape, and translucency of endosperm) and cooking and eating qualities (volume expansion, fluffiness, cooked kernel elongation, firmness/stickiness, mouth feel, and pleasant aroma) [2, 22]. Ghanaians have preference for high-quality rice. As stated earlier, the Ghanaian market prefers long slender aromatic grains which become fluffy when cooked [2, 21]. Most of the test hybrids had their grain length to width ratio greater than 3.0 and were classified as slender [31]. The absence of aroma (fragrance) in any of the test hybrid was quite disturbing. Aroma is an important grain quality trait for rice varietal adoption in Ghana. It enhances the market competitiveness of new rice varieties [2, 22]. Development of high yielding aromatic hybrids should therefore be a priority of the local hybrid rice breeding program to enhance adoption. Evaluation of other grain quality attributes (milling and sensory) is recommended for the promising hybrids to make a final decision on their grain quality.

5. Conclusion

Four promising hybrids (SWARNA 2, ARGH 1501, ARGH 1502, and ARGH 1503) with mean yield advantage range of 15–20.8% were identified for further evaluations. With the exception of few hybrids which were particularly susceptible to blast and bacterial leaf blight at certain locations, all the test hybrids had appreciable levels of resistance to blast and bacterial leaf blight. Most of the test hybrids had slender grains but none was aromatic. The results support the possibility of identifying high yielding adapted hybrids through introduction and testing of hybrids from different sources.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

There are no conflicts of interest between authors and partners who supported this work.

Acknowledgments

Many thanks are due to the Alliance for a Green Revolution in Africa (AGRA) for funding part of this research through the West Africa Centre for Crop Improvement (WACCI), University of Ghana. Many thanks are also due to Wienco Ghana, Advanta Seeds Company, and the Agricultural Technology Transfer Project (ATTP) for providing the hybrid seeds and additional funding.

References

[1] C. Ragasa, A. Dankyi, P. Acheampong, A. N. Wiredu, and A. Chapoto, "Patterns of adoption of improved rice technologies in Ghana," *International Food Policy Research Institute*, vol. 35, pp. 1–36, 2013.

[2] D. Asante, B. O. Asante, G. K. Acheampong et al., "Farmer and consumer preferences for rice in the Ashanti region of Ghana: implications for rice breeding in West Africa," *Journal of Plant Breeding and Crop Science*, vol. 5, no. 12, pp. 229–238, 2013.

[3] C. Ragasa and A. Chapoto, "Limits to green revolution in rice in Africa: the case of Ghana," *Land Use Policy*, vol. 66, pp. 304–321, 2017.

[4] P. A. Seck, A. Diagne, S. Mohanty, and M. C. S. Wopereis, "Crops that feed the world 7: rice," *Food Security*, vol. 4, no. 1, pp. 7–24, 2012.

[5] G. S. Khush, "What it will take to feed 5.0 billion rice consumers in 2030," *Plant Molecular Biology*, vol. 59, no. 1, pp. 1–6, 2005.

[6] L.-P. Yuan, "Development of hybrid rice to ensure food security," *Rice Science*, vol. 21, no. 1, pp. 1-2, 2014.

[7] L. Yuan, "Progress in super-hybrid rice breeding," *Crop Journal*, vol. 5, no. 2, pp. 100–102, 2017.

[8] M. H. Khan, Z. A. Dar, and S. A. Dar, "Breeding strategies for improving rice yield-a review," *Agricultural Sciences*, vol. 6, no. 5, pp. 467–478, 2015.

[9] T. Fischer, D. Byerlee, and G. Edmeades, *Crop Yields and Global Food Security; Will Yield Increase Continue to Feed the World?*, Australian Centre for International Agricultural Research, Canberra, Australia, 2014.

[10] S. Virmani, *Heterosis and Hybrid Rice Breeding*, Springer Science & Business Media, Vol. 22, Springer Science & Business Media, Berlin, Germany, 1994.

[11] IRRI, *Hybrid Rice Breeding Manual*, International Rice Research Institute, Los Banos, Laguna, Philippines, 1997.

[12] S. S. Virmani, E. A. Siddiq, and K. Muralidharan, "Advances in hybrid rice technology," in *Proceedings of 3rd International Symposium on Hybrid Rice*, Hyderabad, India, November 1996.

[13] R. A. El-namaky and M. Demont, "Hybrid rice in Africa : challenges and prospects," in *Realizing Africa's Rice Promise*, M. C. S. Wopereis, D. E. Johnson, N. Ahmadi, E. Tollens, and A. Jalloh, Eds., pp. 173–178, CAB International, Oxfordshire, UK, 2013.

[14] D. J. Spielman, D. E. Kolady, and P. S. Ward, "The prospects for hybrid rice in India," *Food Security*, vol. 5, no. 5, pp. 651–665, 2013.

[15] S.-H. Cheng, L.-Y. Cao, J.-Y. Zhuang et al., "Super hybrid rice breeding in China: achievements and prospects," *Journal of Integrative Plant Biology*, vol. 49, no. 6, pp. 805–810, 2007.

[16] C. H. Shi-hua, C. A. O. Li-yong, Y. A. N. G. Shi-hua, and Z. H. A. I. Hu-qu, "Forty years' development of hybrid Rice: China' s experience developmental history of hybrid rice experience of hybrid rice breeding," *Rice Science*, vol. 11, pp. 225–230, 2004.

[17] R. El-namaky, S. Sedeek, Y. D. Moukoumbi, R. Ortiz, and B. Manneh, "Microsatellite-aided screening for fertility restoration genes (Rf) facilitates hybrid improvement," *Rice Science*, vol. 23, no. 3, pp. 160–164, 2016.

[18] S. K. Nustugah, W. Dogber, J. K. Twumasi et al., "Prevelence of rice blast and varietal screening in Ghana," *Journal of Science and Technology*, vol. 25, pp. 18–34, 2005.

[19] S. Nutsugah, J. Twumasi, J. Chipili, Y. Sere, and S. Sreenivasaprasad, "Diversity of the rice blast pathogen populations in Ghana and strategies for resistance management," *Plant Pathology Journal*, vol. 7, no. 1, pp. 109–113, 2008.

[20] M. D. Asante, S. K. Offei, V. Gracen et al., "Starch physicochemical properties of rice accessions and their association with molecular markers," *Starch*, vol. 65, no. 11-12, pp. 1022–1028, 2013.

[21] B. T. Anang, S. N. A. Adjetey, and S. A. Abiriwe, "The consumer preferences for rice quality characteristics and the effect on price in the Tamale Metropolis, Northern Region, Ghana," *International Journal of Agriculture Sciences*, vol. 1, pp. 67–74, 2011.

[22] D. Asante, B. O. Asante, G. K. Acheampong et al., "Grain quality and determinants of farmers preference for rice varietal traits in three districts of Ghana: implications for research and policy," *Journal of Development and Agricultural Economics*, vol. 5, no. 7, pp. 284–294, 2013.

[23] G. Acquaah, *Principles of Plant Genetics and Breeding*, Blackwell Publishing, London, UK, 2nd edition, 2009.

[24] R. W. Zobel, M. J. Wright, and H. G. Gauch, "Statistical analysis of a yield trial," *Agronomy Journal*, vol. 80, no. 3, p. 388, 1988.

[25] W. Yan, L. A. Hunt, Q. Sheng, and Z. Szlavnics, "Cultivar evaluation and mega-environment investigation based on the GGE biplot," *Crop Science*, vol. 40, no. 3, pp. 597–605, 2000.

[26] W. Yan and N. A. Tinker, "Biplot analysis of multi-environment trial data: principles and applications," *Canadian Journal of Plant Science*, vol. 6, 2006.

[27] A. Verma, R. Chatrath, and I. Sharma, "AMMI and GGE biplots for G×E analysis of wheat genotypes under rain fed conditions in central zone of India," *Journal of Applied and Natural Science*, vol. 7, no. 2, pp. 656–661, 2015.

[28] S. K. Yau, "Regression and AMMI analyses of genotype × environment interactions: an empirical comparison," *Agronomy Journal*, vol. 87, no. 1, pp. 121–126, 1995.

[29] R. O. Akinwale, M. A. B. Fakorede, B. Badu-Apraku, and A. Oluwaranti, "Assessing the usefulness of GGE biplot as a statistical tool for plant breeders and agronomists," *Cereal Research Communications*, vol. 42, no. 3, pp. 534–546, 2014.

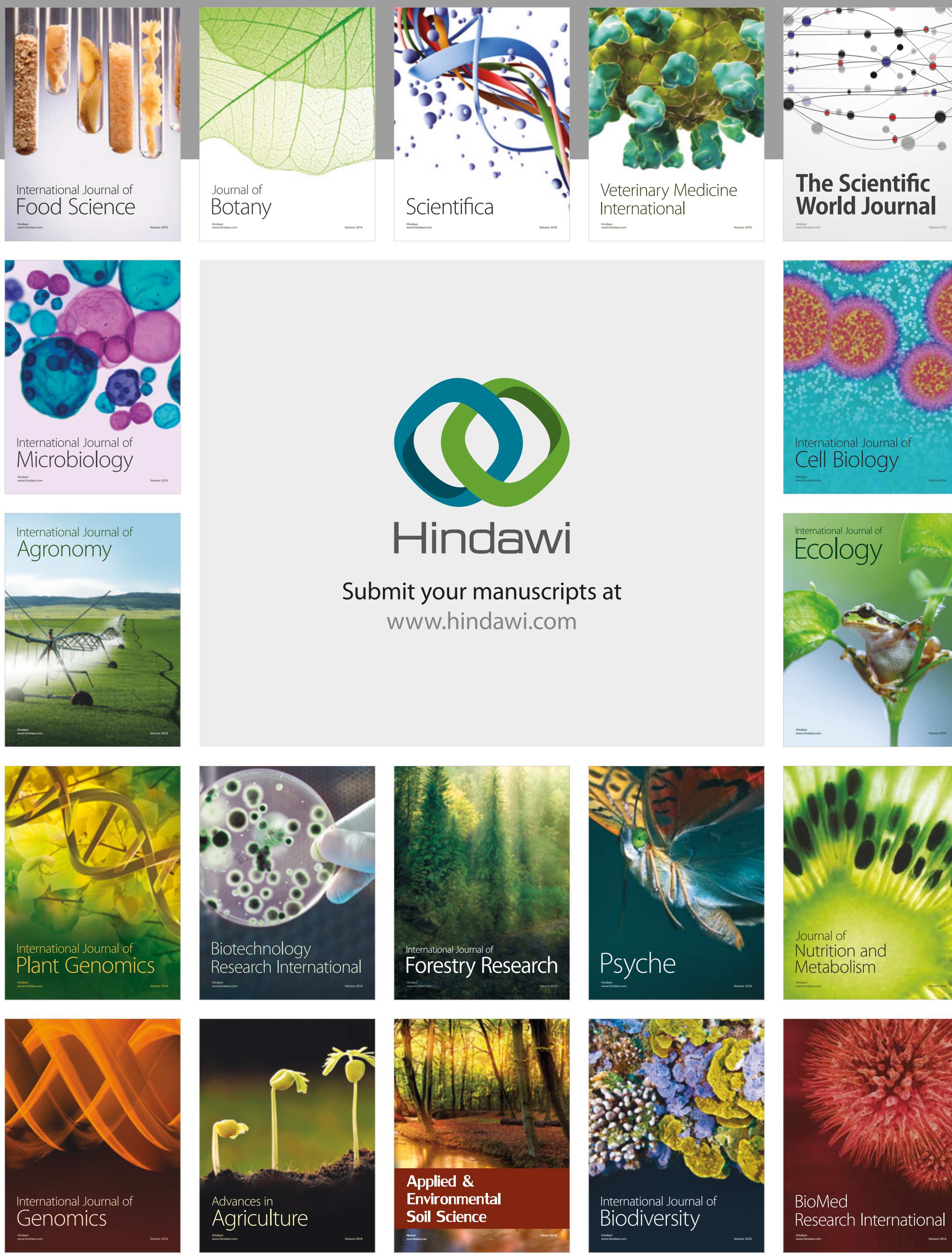
[30] E. Frutos, M. P. Galindo, and V. Leiva, "An interactive biplot implementation in R for modeling genotype-by-environment interaction," *Stochastic Environmental Research and Risk Assessment*, vol. 28, no. 7, pp. 1629–1641, 2013.

[31] IRRI, *Standard Evaluation System (SES) for Rice*, International Rice Research Institute, Los Banos, Philippines, 5th edition, 2013.

[32] R. Payne, D. A. Murray, S. A. Harding, D. B. Baird, and D. M. Soutar, *Genstat for Windows (12th Edition) Introduction*, VSN International, Hemel Hempstead, UK, 2009.

[33] G. Kanfany, R. El-namaky, K. Ndiaye, K. Traore, and R. Ortiz, "Assessment of rice inbred lines and hybrids under low fertilizer levels in senegal," *Sustainalbility*, vol. 6, no. 3, pp. 1153–1162, 2014.

[34] P. Pandey and D. K. Tiwari, "Modern techniques and agronomic packages for hybrid rice cultivation in India," *Advances in Agriculture and Botanics*, vol. 4, pp. 17–21, 1994.


International Journal of
Food Science
Journal of
Botany
Scientifica
Veterinary Medicine
International
The Scientific
World Journal
International Journal of
Microbiology
Hindawi
Submit your manuscripts at
www.hindawi.com
International Journal of
Cell Biology
International Journal of
Agronomy
International Journal of
Ecology
International Journal of
Plant Genomics
Biotechnology
Research International
International Journal of
Forestry Research
Psyche
Journal of
Nutrition and
Metabolism
International Journal of
Genomics
Advances in
Agriculture
Applied &
Environmental
Soil Science
International Journal of
Biodiversity
BioMed
Research International