Chapter

Hybrid Rice in Africa: Progress, Prospects, and Challenges

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Abstract

Hybrid rice varieties exploit the phenomenon of heterosis to out-yield their inbred counterpart to increase productivity per unit area. Unlike inbred rice varieties whose seeds could be used for replanting season after season, farmers will have to purchase seeds of hybrids every season to obtain the expected yield and other quality attributes. While the hybrid system is a disadvantage to farmers in terms of mandatory seed purchase, it serves as a motivation and opportunity for private seed companies to recoup their investment and therefore encourages their involvement in seed production research and development. Hybrid rice technology originated from China and is well commercialized in Asia and the Americas. Africa is among the few places where hybrid rice is still not fully commercialized. Besides Egypt, many African countries have just begun to exploit the benefits of hybrid rice technology. A number of introduced hybrids have exhibited a 15–20% yield advantage over the available top inbred varieties. Most African countries also have a conducive environment for viable hybrid rice seed production. Besides other pertinent challenges, some which can be addressed technically, there should be a recommended production package that will give farmers the best of yield to enable hybrid rice contribute to attaining rice self-sufficiency in Africa.

Keywords: rice, hybrid rice, Africa, increasing rice productivity, hybrid rice adoption

1. Introduction

Although over 90% globally is produced and consumed in Asia, rice is the fastest growing food source in Africa. In Sub-Saharan Africa (SSA), consumption is estimated to be increasing at a rate of 6% per annum, the highest in the world [1]. The rate of increase in consumption of rice in Africa has not been matched by corresponding increases in production and the demand-supply gap keeps widening. It is estimated that Africa imports 36% of its annual rice requirement (18 million metric tons) at a cost of US$7 billion per annum (FAO, 2019). The continuous dependence on imports places a heavy demand on scarce foreign currency reserves of the countries in the region, which are among the poorest in the world. In order to address this situation, national and international institutions as well as bilateral and multilateral donors formed a consultative group on rice known as the Coalition for African Rice Development (CARD). The goal of CARD was to double rice production in Africa by 2018. Nevertheless, due to outdated production systems, biotic and abiotic constraints as well as low investment in production technologies, only about 60% of the consumer demand is still met through local production [2]. As a response to the 2008 rice crisis and other challenges such as population growth, rapid urbanization, climate change, and natural resource degradation, national, regional, and international institutions have increased investment toward boosting rice production on the continent. Consequently, many countries have national strategic plans and favorable policies for increasing rice production in place. The current situation is encouraging and requires strengthening existing partnerships to address the challenges across the whole rice value chain to enhance sustainable food security across the continent [2].

Promoting the adoption of productivity enhancing technologies including hybrid rice technology is key to the continent's rice self-sufficiency agenda. Hybrid rice has the penitential of increasing rice productivity and encouraging private sector involvement in seed production research and development in Africa. Since there is currently no proper plant variety protection (PVP) system in place in most of Sub-Saharan countries; the hybrid system could serve as a form of biological intellectual property through the control of the hybrid parents. This chapter examines the procedures of hybrid rice development, current state of development and commercialization in Africa as well as its prospects and challenges.

2. Rice breeding methods

Rice breeding is an effective mechanism for delivering the benefits of science and technology to millions of resource-poor farmers. Rice is considered one of the crops that has achieved remarkable success through breeding. Notable success includes the contribution to the green revolution with semi-dwarf varieties that averted a looming hunger in Asia in the 1960s [3, 4]. The methods of breeding rice can be categorized into conventional selection, in-vitro, molecular and transgenic. The available conventional selection breeding methods include mass selection, pure line selection, pedigree method, bulk method, backcross method, recurrent selection, and single seed descent [5, 6]. Mass and pure line selections are mostly used for purifying heterogeneous varieties and are rarely used in present day breeding programs. The pedigree method is the most widely used method to develop rice varieties. More than 85% of the released rice varieties were developed through pedigree selection [4]. Backcrossing is commonly used to incorporate one or a few genes into an adapted or elite variety [4–6]. Although hybrid breeding is primarily applicable to outcrossing species such as maize, it has been successfully added to the rice breeding portfolio. The aim of hybrid rice breeding is to raise the yield ceiling of rice beyond what is currently achieved by the semi dwarf varieties [7, 8]. Mutagenesis to some extent has also been employed to develop some valuable rice varieties [4, 9]. The in-vitro methods include tissue culture techniques such as anther culture to develop doubled haploids, somaclonal variation to identify useful variants and embryo rescue to assist in wide hybridization such as the one that led to the development of the NERICAs. In the NERICA development, embryo rescue was used to obtain viable progeny between *Oryza sativa* and *Oryza glaberrima* crosses [10]. Molecular breeding methods mostly involve the use of molecular markers in marker assisted selection to increase the efficiency and precision of conventional breeding [6, 11]. Genetic engineering (transgenic technique) allows addition of alien genes from any living organism to the rice gene pool to impart a useful function. This technique allows breeders to accomplish objectives which cannot be achieved through conventional plant breeding [12]. Quite recently, genome editing technique has been added to the rice breeding methods. By genome editing, specific modification can be made at targeted locations of the rice genome. Unlike genetic engineering, this method does not involve the introduction of foreign genes into the rice genome [13].

2.1 Rice varietal types

The above breeding methods lead to the development of one of the three main rice varietal types i.e. inbreds (pure lines), hybrids or GM (transgenic) rice [6]. Inbreds are the most commonly used rice varietal type. Since offspring or succeeding generations produced by these varietal types are of the same genetic makeup, seeds harvested from an inbred variety can be used for succeeding planting without losing their varietal identity provided cross pollination with other varieties is avoided. Hybrids are products of crossing two genetically diverse inbred lines. As a result, seeds harvested from the hybrid plants are not recommended for replanting because some vigor is lost resulting in lower yield and genetic segregation [8]. Farmers are recommended to buy new hybrid seeds for each planting season from accredited sources. The increased profits resulting from increased yields of hybrids versus pure line varieties offset the cost of the hybrid seed. Transgenic (GM) rice results from the use of genetic engineering. Though the resulting varieties breed true, they are separated from the conventional (nontransgenic) inbreds due to the involvement of a transgene. Though several transgenic rice lines have been developed, they are yet to find their way into commercial cultivation. Notable transgenic (GM) rice is the Golden rice; a variety engineered to produce beta carotene to help combat vitamin A deficiency [12].

3. Hybrid rice technology

Hybrid rice is the commercial rice crop grown from F_1 seeds of a cross between two genetically dissimilar parents. This could only be possible through the use of a male sterility system due to the strictly self-pollination nature of the rice plant [4, 8]. Hybrid varieties exploit the phenomenon of hybrid vigor (heterosis) to increase the yield potential of rice beyond the level of modern inbred rice varieties. A yield advantage of 15–30% over conventional inbred varieties grown under similar conditions has been reported [14]. The hybrid rice technology concept dates back to 1964 in China. However, it was only after 1976, when a wild abortive pollen plant was identified in Southern China, did the idea begin to materialize [4, 8]. Since the expression of heterosis is confined to the first generation only, farmers have to buy fresh seeds every season to raise commercial crop. Since the hybrids yield 15 to 30% more than pure line varieties, farmers prefer hybrid seeds if the price is economically beneficial and seeds are readily available. Hybrids can offer biological intellectual property protection which attracts and encourages private-sector involvement in seed production research and development [15].

3.1 Genetic basis of heterosis

For a long time, two theories; the dominant and overdominance theories were put forward to explain the phenomenon of heterosis [14]. According to the dominant theory, hybrid vigor is due to the action and interaction of favorable dominant alleles. The overdominance theory on the other hand suggests that heterozygous loci are superior to homozygous loci. Thus, two alleles complement each other and there is overexpression of genes in the heterozygous state [16]. Recently, epistasis or interactions among loci has been recognized as a major contributor to heterosis [17]. Estimates based on mating designs of the relative magnitude of additive, dominance and epistatic components of variance indicate that the magnitude of epistatic variance is small compared to additive and dominance components. This is because statistical designs cannot predict epistasis. Using molecular markers, Yu *et al*. [18] provided evidence of the importance of epistasis as a possible genetic basis of heterosis in rice. Since none of these theories exclusively explains heterosis, suggestions are to ascribe the phenomenon to a combination of the three models.

4. Hybrid rice breeding methods

4.1 The CMS (three-line) method

Hybrids rice is currently produced either by the three-line (CMS) or the two-line (EGMS) method [19]. The three-line method employs three lines; the CMS (A line), maintainer (B line) and restorer (R line). An A-line is genetically identical to the B-line except that the B-line has a normal (N) cytoplasm while the A-line has a male sterile (S) cytoplasm. An R-line has dominant fertility restorer genes in its nucleus which restore male fertility to the F_1 hybrid. The B-line is crossed to the A-line to maintain/produce seeds of the A-line whiles the R-line is crossed to the A-line to produce hybrid seeds.

4.1.1 Organization of hybrid rice breeding program using the CMS system

Due to the relatively complex nature of the three-line (CMS) breeding system, breeding materials are grouped into separate nurseries or stages for efficient handling and development of parental lines. Experimental hybrids normally pass through the required stages and are finally tested on farmers' fields before their release. The nurseries include the source nursery, the testcross nursery, backcross nursery, re-testcross nursery and combining ability nursery [19]. The source nursery contains elite breeding and CMS lines with the potential of becoming parents of commercial hybrids. In the testcross nursery, F_1s from the CMS and tester lines in the source nursery are evaluated for their pollen and spikelet fertility to identify prospective maintainers (B-lines) and restorers (R-lines). Re-testcross nursery is for confirming and purifying prospective R-lines and backcross conversion of prospective B lines into CMS lines. Combining ability nursery evaluates general and specific combining abilities of selected CMS and R lines. This nursery helps identify higher yielding hybrids and is very crucial in the hybrid rice development process [17, 19]. Various modifications of the IRRI's system described above are made to improve breeding efficiency. Elite tester inbreds are selected from R-lines to cross onto new A-lines and select testers from A and B-lines to identify new R-lines. Once commercial R and A-lines are identified, they are used as testers instead of crossing a bunch of new R-lines by new A-lines. For instance, in China, IRRI's elites IR24, IR26 were directly used as restorer lines. These restorers were also used as restorer gene resources to develop new restorer lines [17]. Conversion of identified maintainer into a CMS line. Often lines introduced to new areas are not adapted to the target environment. They may be susceptible to particular local pests and diseases or may lack the desirable grain quality attributes. This necessitates the conversion of the available CMS lines into locally adapted and desirable ones. Introduced CMS lines maintainer identified from a cross of local lines onto a CMS source should be backcrossed to develop adapted CMS lines [19]. Backcrossing is continued to the 5th -6th generation (BC_5-BC_6) where the nuclear content of the original CMS source is replaced almost completely with that of its corresponding maintainer. Development of new CMS lines is normally difficult due to the limited chances of identifying stable sterile lines from local germplasm [19]. Developing new CMS lines using African cultivars has proven difficult due to sterility instability in the BC_1 and BC_2 generations [15].

4.2 The two-line method

In this system, male sterility is conditioned by the interaction of nuclear genes with environmental factors such as photoperiod, temperature or both. Such lines are referred to as environment-genetic male sterility (EGMS). The ones conditions by lines temperature are technically known as thermosensitive-genetic male sterility (TGMS), ones by photoperiod are photo-genetic male sterility (PGMS) and by both temperature and photoperiod are referred to as photo-thermo-genetic male sterility [17, 20]. Organization and seed production are simpler in this system than the CMS system. The EGMS lines are multiplied by sowing these lines in such a way that the sensitive period coincides with photoperiod/temperature that is conducive for inducing fertility. Hybrid seed production is taken up by sowing these lines in such a way that the sensitive stage coincides with the photoperiod or temperature conducive for inducing complete male sterility [20]. Magnitude of heterosis in two-line hybrids is 5 to 10% higher than in three-line hybrids. The major constraints to developing and using TMGS lines in the tropics are limited availability of stable TGMS germplasm. Since the PGMS, TGMS and PTGMS are controlled by recessive gene (s), when these lines are crossed with a fertile line, the hybrids are fully fertile, irrespective of the day length and temperature conditions prevailing during the growth season. Although attractive and potential as a tool for exploiting heterosis, the EGMS system has some advantages and disadvantages. Compared to the two-line system, the use of the three-line system is expensive and labor intensive but much more reliable. Since the two-line system does not require a maintainer line, any line can be used as pollen donor. This increases the chances of identifying higher yielding hybrids in the two-line system than the three-line system. However, any sudden changes in the environmental conditions during the hybrid production season affect the sterility of the temperature sensitive line and the requirement of additional land in different day length areas limits the ability to reliably produce hybrid rice using the two-line system [20].

5. Identification of high-yielding hybrids

After a large number of prospective parental lines (CMS, restorers or EGMS) have been identified, there is the need to select the most promising ones by their ability to give superior hybrids. This is normally achieved using the line by tester design [17]. Although it is still not well understood, the positive correlation between genetic distance of hybrid parents and the resulting F_1 heterosis is accepted phenomenon. Heterosis levels in rice are reported to increase in the direction of *Japonica* × *japonica* < *indica* × *indica* < japonica × *javanica* < *indica* × *javanica* < *indica* × *japonica* [14]. Utilization of intersubspecific heterosis has been regarded as a promising strategy for increasing rice productivity. Large efforts have been invested in the last decades for breeding *indica–japonica* hybrids. However, such efforts have been hindered by hybrid sterility that frequently occurs in intersubspecific crosses. Discovery of Wide Compatibility Varieties (WCVs) brought hope for breaking the sterility barrier between *indica* and *japonica* subspecies and provided a possibility for exploiting the strong heterosis between them. The WCVs could produce fertile F_1 hybrids when crossed with *Indica* or *Japonica* lines. The key approach was to introduce wide compatible genes into the restorer or CMS lines for developing widely compatible restorer or CMS lines which will permit the production of fertile F_1 hybrids from either subspecies. Through marker-assisted selection, Guo *et al*. [21] successfully pyramided the *indica* allele (*S*-i) at four loci (*Sb*, *Sc*, *Sd* and *Se)* and the neutral allele (*S*-n) at *S5* locus in *japonica* genetic background to develop

Indica-Compatible *Japonica* Lines (ICJLs). These lines have a great promise of overcoming the intersubspecific hybrid sterility and exploiting the high heterosis between them. There is also a super hybrid rice breeding project in China trying to exploit intersubspecific heterosis in combination with ideal plant type [17].

6. Enhancing outcrossing in hybrid rice seed production

Various natural and artificial methods are employed to increase outcrossing rate in hybrid rice seed production. Among the artificial ones are flag leaf clipping, gibberellin application and supplementary pollination [14]. Besides, there are several traits that naturally contribute to hybrid rice seed production efficiency. These include days to heading, pollen load, pollen longevity, and morphological traits of floret such as size of stigma and style, stigma exertion, stigmatic receptivity and spikelet opening angle. Stigma exertion rate is emphasized as a key factor for efficient hybrid rice seed production [14]. The extent to which the stigma is exerted in the female parent (male sterile line) increases the chances of outcrossing thereby increasing hybrid seed set. Stigma exertion is a genetic trait and not all male sterile lines possess high expression of it. It is therefore possible to enhance the trait through specific breeding efforts using appropriate donors. Both qualitative and quantitative modes of inheritance have been reported for stigma exertion. Besides several quantitative trait loci (QTL) controlling stigma exertion have been mapped to different rice chromosomes [22] with molecular markers and can easily be introgressed into other parents.

7. Attempts at development and commercializing hybrid rice in Africa

Egypt is the only African country that has successfully developed local rice hybrids in commercial scale. Hybrid rice research in Egypt started around 1982 and intensified since 1995 with the launching of a mission-oriented project through a cooperation between Rice Research Program of Egypt and International Rice Research Institute (IRRI). Since then, hybrid rice varieties have been developed and released to help Egyptian farmers improve productivity and increase production [23, 24]. In conjunction with Africa Rice Center (AfricaRice), several African countries started introducing and evaluating hybrid rice mostly from Asia. AfricaRice started a hybrid rice breeding program to developed hybrid varieties for the sub-Saharan Africa region starting from the year 2000 [15]. For a start, the AfricaRice program tried to build on hybrids developed by the Green Super Rice project jointly coordinated by the Chinese Academy of Agricultural Sciences (CAAS), AfricaRice and IRRI. Hybrids from the project were evaluated for yield and general adaptability in the rainfed and irrigated ecologies of eight African countries (Liberia, Mali, Mozambique, Nigeria, Rwanda, Senegal, Tanzania and Uganda) [15]. Although promising hybrids out-yielded the best inbred checks, they were susceptible to the major pest and diseases in the region [15, 25]. This necessitated the development of AfricaRice's in-house hybrids program with the following objectives: (i) develop new parental lines from local varieties; (ii) determine adaptability of some CMS lines in Africa; and (iii) establish a hybrid rice seed production system in some African countries [15]. About 50 high-yielding hybrid rice lines were developed and evaluated in several African countries by the AfricaRice program [25]. Notable among them is the aromatic hybrid rice variety (AR051H) released in 2017 by the Senegalese Institute of Agricultural Research under the name ISRIZ 09. AfricaRice and CORAF through donor support projects have been showcasing and promoting the adoption of hybrid rice technology in some Sub-Saharan African countries. Initial studies on local hybrid rice seed production in some West African countries indicate no technical hindrance since a seed yield of about 1–2 t/ha could be obtained in many of these countries [15].

Aside the AfricaRice's program, the African Agricultural Technology Foundation (AATF) is working with partners to develop new indigenous rice hybrids that can increase rice yields and improve productivity for farmers in the Eastern and Southern Africa. Unlike AfricaRice's program which uses the CMS (three-line) system, the AATF project dubbed "breeding by design" uses the thermosensitive (two-line) system [26]. The partnership intends to develop hybrid rice germplasm that is adapted to African conditions using the 2-line hybrid rice system. Under the partnership, an information technology tool with interpolated weather surfaces to predict temperature regimes and manage 2-line hybrid rice production risk is being established. The project as well intends to train a network of researchers and seed production specialists interested in 2-line hybrid rice. The broad objective of the AATF partnership is to develop and expand 2-line hybrid rice technology in selected African countries and ensure that through private companies and public institutions in Africa, this technology reaches farmers and increases their rice yields and income. As support for hybrid rice on the African continent increases, the AATF and its partners including IRRI have formed the Alliance for Hybrid Rice in Africa (AHyRA). The key objectives for AHyRA initiative are to:

1. Promote collaboration and business integration between stakeholders of rice value chains to develop, produce and market hybrid rice seeds.

2. Create a consolidated advocacy for an enabling environment for the sustainable use of hybrid rice in Africa.

3. Conduct joint adaptability testing of available hybrid rice varieties

4. Generate a robust database for parental lines and hybrid rice for the use of stakeholders, and private seed companies, particularly in Sub-Saharan Africa.

5. Strengthening the capacity of partners on the hybrid rice technologies.

Other National Agricultural Research systems (NARs) in collaboration with multi-national and local private seed companies also initiate their own in-country hybrid rice development and commercialization endeavor. For instance, NARS in Ghana in collaboration with international and local private seed companies (WIENCO, ADVANTA and SEED CO.) have conducted studies into farmer preferred traits and potential for adoption of hybrid rice [27] in Ghana, evaluated introduced rice hybrids for yield, rection to disease and grain quality attributes [28]. A study has also been conducted to identify CMS maintainers and restorers for local hybrid rice development [29]. Although these efforts have led to the release of two hybrid rice varieties with 15–20% yield advantage over the best inbred check, promotion and commercialization is still low. Plans for in-country hybrid rice seed production has also not been materialized and seeds of these hybrid are still imported. Mali in collaboration with IRRI initiated its own hybrid rice development program in early 2011 [15]. A summary of countries involved in hybrid rice research and development and their status and collaborators is presented in **Table 1**. Examples of some released hybrid rice varieties on the African continent is presented in **Table 2**.

Country	Status	Collaborating institutions/ projects
Egypt	Grow locally developed hybrid rice varieties	Rice Research and Training Centre, IRRI, FAO
Ghana	Identification of farmer preferred traits, evaluation of introduced hybrids, identification of CMS maintainers and restorers,	Advanta, Seed Co, Wienco-Ghana
Mali	Evaluation of introduced hybrids, identification of CMS maintainers and restores	IRRI/AfricaRice hybrid rice projects
Mozambique	Evaluation of introduced hybrids	AfricaRice hybrid rice breeding program
Nigeria	Evaluation of introduced hybrids	AfricaRice hybrid rice breeding program
Senegal	Evaluation of introduced hybrids	AfricaRice hybrid rice breeding program
Tanzania	Evaluation of introduced hybrids	AfricaRice/AATF hybrid rice breeding programs
Uganda	Evaluation of introduced hybrids	AfricaRice hybrid rice breeding program
Kenya	Evaluation of introduced/developed hybrids	AATF hybrid rice project

IRRI, International Rice Research Institute; AATF, African Agricultural Technology Transfer; AfricaRice, Africa Rice Center; FAO, Food and Agricultural Organization.

Table 1.
African countries involved in hybrid rice research and development and their status.

Hybrid	Released country	Institution
AR051H (ISRIZ 09)	Senegal	Senegalese Institute of Agricultural Research
PAC 801	Ghana	CSIR-Savanna Agricultural Research Institute
Arize 6444 Gold	Ghana	CSIR-Crops Research Institute
EHR1 (SK2034)	Egypt	Rice Research and Training Centre
EHRI2 (SK2046)	Egypt	Rice Research and Training Centre
EHR3 (SK2151H)	Egypt	Rice Research and Training Centre

Table 2.
Examples of released hybrid rice varieties on African continent.

8. Prospects of hybrid rice in Africa

Hybrid rice has the potential to help increase rice production and productivity as well as reducing rice imports in Africa. The main tenet of hybrid rice technology is to employ the phenomenon of heterosis to out yield the available inbred semi-dwarf varieties. A yield advantage range of 15–20% over available inbred checks reported in other parts of the world has also been recorded in Africa [15, 24, 25, 28]. Scaling up and promoting adopting of these hybrids, will contribute to food security in general on the African continent. It will also enable majority of the populace afford to buy their staple food at reasonable prices thereby helping to maintain political stability. Improving rice productivity on the African continent has relied heavily on increasing land area which is unsustainable. Hybrid rice technology has the ability to help save land required for rice production and put into other productive uses. The technology also could encourage private sector involvement in the rice seed research and development. One challenge for multi-nationals and other local private seed companies engaged on the African continent has been the unavailability of a functional plant variety protection (intellectual property) systems to protect their new varieties. Since the hybrid system provides some sort of biological intellectual property through the control hybrid parents, seed companies could operate effectively to recoup their investment. This in turn will assure farmers access to quality rice seed which normally is a challenge to improve rice productivity on the African continent. Hybrid rice cultivation requires fresh F_1 seed for every cropping season. This will require the development of a functional hybrid seed production, processing and marketing infrastructure in the form of seed enterprises (public, private or NGOs). This has the potential to create additional rural employment opportunities for the rural folk mostly youth and women. Introduced hybrids were found to exhibit substantial yield advantage under both rainfed and irrigated lowland ecologies [25]. These two ecologies form a large portion of the available area for rice cultivation. Thus, hybrids varieties could be promoted widely among rice production regions of Africa. There seems to be an emerging interest by donor and international agencies working toward achieving rice self-sufficiency on the African continent to position hybrid rice as a technology that can contribute to a food secured Africa. Promotion of locally adapted high yielding varieties developed by AficaRice currently enjoys some donor support through technologies for African agricultural transformation (TAAT) rice compact and the West and Central African Council for Agricultural Research and Development (CORAF). This involves working toward the right policies and infrastructural requirements to make this technology thrive and such a concerted effort is bound to chalk some success.

9. Challenges of hybrid rice adoption

Like other continents, Africa will have to overcome the major constraints to large scale adoption of hybrid rice. These include high cost of seeds, poor grain quality issues, pest and diseases susceptibility, human capacity for hybrid rice development and the difficulty of identifying higher heterosis (> 25%) at the field level [30]. Most African rice farmers have built a tradition of using self -saved seeds. This tradition, maybe, was to adapt to the unavailability of adequate reliable seed companies to ensure timely supply of quality rice seeds. Most rice farmers still use traditional varieties. For the few that use improved varieties, it is through the informal system. The business of rice seed production is at the budding stage and will have to be developed before hybrid varieties could have a place. Most African governments still ensures that their farmers get the benefits of improved seeds through the subsidy. The major challenge for hybrid rice includes whether African rice farmers will be willing to buy hybrid seeds for every cropping season and to do so at a higher price. The hybrid rice technology itself could also act as a catalyst to creating a sustainable rice seed business by providing varieties with high yield advantage which can attract farmers to patronize improved rice varieties. That means the realizable yield advantage of hybrids on the field should be high enough. Although initial studies suggest that farmers anticipate above 30% yield advantage over existing best inbred to guarantee adopting a variety that requires seasonal seed purchase [27], there is a technical limitation to the realizable field heterosis by hybrid varieties.

Sub-Saharan Africa is among the few places globally where rice yields are still low with average yield of about 2.2 t/ha. This is largely due to the use of less productive cultivation technologies and inputs particularly fertilize [31]. Although hybrid varieties perform relatively better under stress conditions, the full potential could be realized under optimal inputs. For African rice farmers to realize the yield benefit of hybrids, there will be the need for hybrid seeds be accompanied with a well-researched and recommended agronomic package that will give farmers the best yield.

Hybrid rice is new to the African continent and knowledge on the technology is limited. There will be the need to train a critical mass of scientists and technicians on hybrid rice research and seed production to spearhead the development, demonstration and adoption of the technology. Aside that, farmers should be educated not to save and replant hybrid seeds.

The African continent is fragmented in terms of essential traits. There will be the need to develop different hybrid combinations for different rice production regions depending on their important traits. Hybrid rice breeding uses concepts, skills, and procedures which are strikingly different from those used for conventional inbred rice development. Unlike conventional inbred rice development which accumulates productive genes that perform well in a homozygous state year after year, hybrid rice breeding exploits hybrid vigor which provides additional genes that add to the yield obtained by the productive genes in the homozygous varieties. Most introduced rice hybrids tend to have problem of susceptibility to local pest and diseases such as blast, rice yellow mottled virus (RYMV) disease and African rice gall midge (AfRGM) [25]. Aside these stresses, poor grain quality was one of the major constraints for large scale adoption of hybrid rice in Asia. Varieties with long slender aromatic grains that cook soft are mostly preferred by consumers within the West African sub-region. Breeders will have to battle with these traits which are mostly quantitatively inherited and difficult to combine in in developing products.

10. Conclusion

There is an emerging interest to position hybrid rice as a technology that can contribute to attaining rice self-sufficiency in Africa. Some African countries have responded by testing promising introduced and in-house hybrids developed by the pan-African rice research institute (AfricaRice). Some of these hybrids have shown favorable yield advantages over the best available inbred lines, but there are reports of susceptibility to some local pest and diseases. Initial studies on seed production potential indicates that most countries have conducive environment for local hybrid rice seed production. Nonetheless, there is the need to train a critical mass of scientists and technicians to champion the hybrid rice agenda and educate farmers not to save and re-plant hybrid rice seeds. There are a number of traits that hybrid breeders should also consider in developing products for the various market segments. For farmers to appreciate the need for buying seeds every season and at a higher price, hybrid varieties with higher field level heterosis should be developed and demonstrated. Also, promotion of hybrid rice seeds should go along with a well-researched recommended crop management package that will give farmers the best of yield. The hybrid rice agenda should form part of the overall strategy to develop a sustainable integrated rice seed sector to benefit African rice farmers.

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