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Development of Hybrid Rice Technology and Sustainable Food Security in Nigeria

Magashi Auwal Ibrahim

ABSTRACT

Food insecurity is a global phenomenon and statistics show that it is more intense in Nigeria and other developing nations. Anything that interrupts food supply and access or interferes with the utilization of food will lead to food insecurity. Fortunately however, unlike many countries, Nigeria is blessed with abundance of arable land for modern agriculture and enormous human resource and agricultural knowledge repository. The paper highlighted the need to increase yield per unit area of rice, one of the most important food resources in Nigeria. It briefly describes the effective scientific method of developing hybrid rice for Food Security. It also showed that, the use of hybrid vigour in first-generation seeds (or F1) is well known in achieving this goal. However, until about 30 years ago, its application in rice was limited because of the self-pollination character of the crop. In conclusion, the paper recommends adoption of Chinese technology of developing hybrid rice using two-line hybrids method, with yield advantages of 5 to 10 percent over those of the equivalent three-line hybrids method.

Keywords: *Food, food security, hybrid rice, rice production*

INTRODUCTION

Rice is one of the most important food crops in Nigeria. However, the amount produced locally does not meet the demand. This is due to some factors still militating against its production, including climate change and natural disasters, low use of technology and other inputs, inadequate attention to critical aspects of

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the value chain such as processing, handling and storage/preservation, amongst others. Therefore, the country mainly depends on imported rice to meet the country demand in rice. This clearly shows the important role of rice production in food security and poverty alleviation in Nigeria and in the whole world. The country will attain "Food Security only when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food references for an active and healthy life" (FAO World Food Summit, 1996). FAO (2002) has recorded that rice covers 147 million hectares, which is 11% of the world's arable land with the annual world production of about 576 million tons and feeds more than half of the world population.

Recent studies revealed that to keep up with population growth, the world's annual rice production must grow to 760 million tons by 2020. However in Nigeria, lack of arable land on which to extend rice production and to meet the demand of Nigerians must therefore be met by increasing the yield per unit land. It has proven for many years that, the development of hybrid rice in early 1970s is a great breakthrough in rice breeding. This provides a very effective approach of increasing rice yield by a big margin success with more than 20% yield advantage over improved inbred varieties. China's experience indicated that the expansion area grown to hybrid rice is a most efficient and economical way to meet the future rice demands of a growing population.

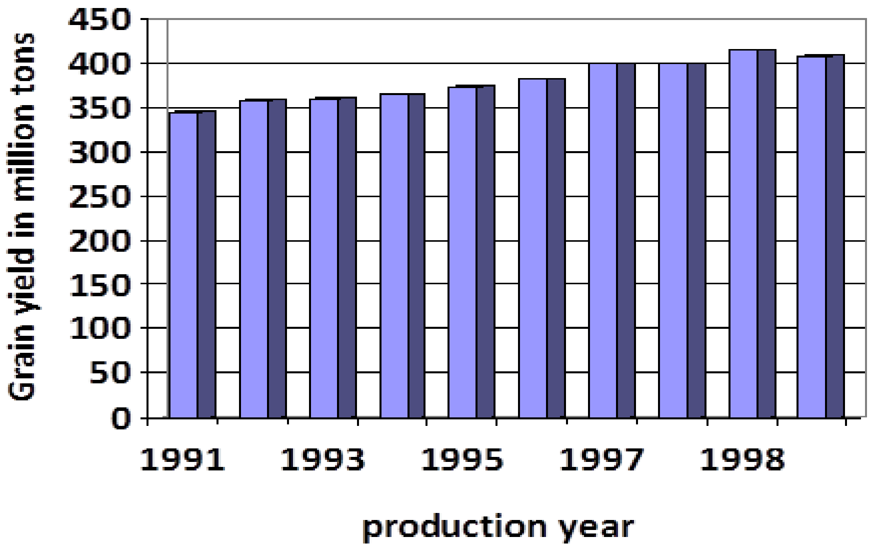

Figure 1: Annual production of rice grain over 8 years (1991-1998) in Nigeria

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Demand in Rice

Annually, Nigerians consume around 5.5 million tons of rice, of which 3.6 million tons are locally produced mostly by farmers for personal consumption. It was estimated that Nigeria currently, spends roughly ¦ 365bn per year importing the remaining 1.9 million tons, because local production is unable to satisfy the huge demand for rice in Nigeria. This figure also makes Nigeria the world's largest importer of rice. So there is a genuine demand and genuine opportunities for entrepreneurs and businesses in Nigeria. This may be seen as great news for entrepreneurs in Nigeria, as it presents legitimate money making opportunities.

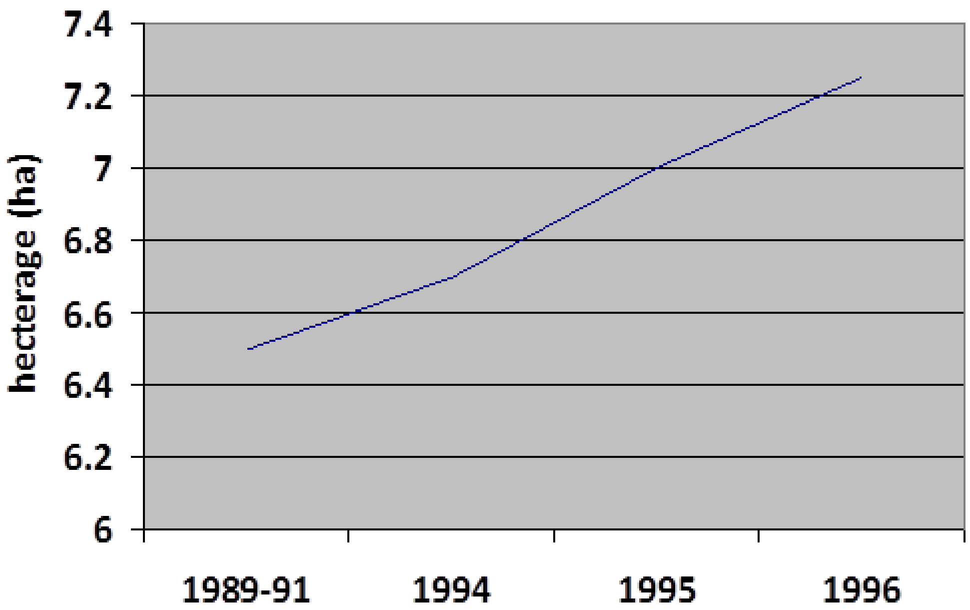

Figure 2: The increasing land area grown to rice in Nigeria from 1989 to 1996

Historical background of Rice Production in Nigeria

In Nigeria local rice cultivation dates back to 16th century, it was cultivated on small plots and pockets of inland valley soils (Fadama) and the local cultivars used were tall (1.5m) and mainly produced under irrigation conditions within latitudes 10°– 14°N. The Rice areas cover mainly Sudan/Sahelian zones of Borno, Yobe, Bauchi, Jigawa, Kano, Zamfara, Katsina, Sokoto, Kebbi and Adamawa States. According to Nwachukwu, Agwu and Ezeh (2018), out of available 4.6 million hectares of land for rice production, only 1.7 million hectares were used practical cultivation in the country (Abbas, Agada and Kolade, 2018).. The cost of these rice imports represents a significant amount of lost earnings for the country in terms of jobs and income. Therefore, Nigerian National Rice Development Strategy (NRDS) set up in 2009 with the objective of making the country self-sufficient in rice by raising production of paddy rice from 3.4 million tons in 2007 to 12.8 million tons in 2018. The NRDS outlines three priority areas of focus to achieve this level of production: (i) improving post-harvest processing and treatment; (ii) developing irrigation and extending cultivated lands; and (iii) making seed, fertilizer and farming equipment more readily available.

Challenges

Weak research-extension-farmer linkage system (REFILS) to improve farmers' technologies in the agronomy of rice production, inadequate skill on the use of biotechnological tools for development of improved rice varieties tolerant to biotic and abiotic stresses, inadequate high yielding blast tolerant varieties and inadequate water and inputs management are the major challenges facing rice production in Nigeria. On the other hand, some Nigerian farmers cannot even afford a bag of fertiliser, for a hectare where you need about six bags. It is so wide, in a farmland where you ought to get seven tonnes of rice, hardly do farmers got up to three tonnes.

WHY HYBRID RICE?

A new opportunity: Increasing attention has been given to the development of a new generation of rice varieties, including hybrid rice, new plant types and transgenic rice. At present, hybrid rice technology for large-scale production has a yield advantage of 15 to 20 percent or more than 1 ton of paddy per hectare, over the best inbred varieties. Successful commercial hybrid rice production has enabled China to diversify agricultural production on millions of hectares of land. Although Chinese rice lands steadily decreased from 36.5 million ha in 1975 to 30.5 million ha in 2000 (0.6 percent per year), the country has been able to feed more than 1 billion people (Shivani, Sree and Reddy, 2000), thanks to the hybrid rice programme raising the national average yield from 3.5 to 6.2 tons/ha (Longping, Xiaojing, Fuming Guohui and Qius Heng, 2015).

Increasing demand for rice: Rice is the most important staple food crop for more than half of the world's population. The increased demand for rice is expected to exceed production in many countries in Asia, Africa and Latin America. World rice production therefore needs to increase, while land, water and labour are all decreasing.

Declining yield growth: World rice production has increased continuously since 1961, but at varying rates. The annual growth rate of yields declined from 2.5 percent in the 1960s to about 1.1 percent in the 1990s, owing to the difficulty of sustaining rice productivity growth as yields increase.

Developing a hybrid rice

Superiority of hybrid rice in grain yield

It has been proven practically over many years that hybrid rice has more than 20 percent yield advantage over inbred varieties. Hybrid rice has bigger and heavier panicle, the panicle weight of hybrid rice varieties being used commercially in China is around 3 grams at a population density of 2.7 to 3.0 million panicles per hectare, 20%-30% more than that of modern high yielding inbred varieties. It also has stronger tillering ability, with early and fast growth of tillers at vegetative stage.

Genetic methods for developing hybrid rice

There are two common genetic methods of developing hybrid rice:

1. Cytoplasmic-genetic male sterility (CMS), it is for developing three-line system of hybrid rice.
2. Photo- or Thermo- sensitive genetic male sterility (PTGMS) for developing two-line system of hybrid rice.

Cytoplasmic-genetic male sterility (CMS)

The tree-line hybrid rice is the cytoplasm-genetic male sterile line (CMS line or A line), the maintainer line (B line) and the restorer line (R line)

Concept of A line

The CMS line refers to a special breeding line whose anthers are abnormal. No pollen or only abortive pollens exist in the CMS anthers, hence no seed can be borne by selfing. The male sterility is caused by the interaction of the sterile cytoplasm and the recessive male sterile genes in the nucleus. But pistil of the CMS line is normal and can produce seeds when pollinated by normal pollens. A desirable CMS line should have not only good agronomic characters but also the following:

a) Stable male sterility (MS): MS should be inherited from generation to generation without any change in pollen sterility and it should not be influenced by environmental changes, especially temperature fluctuation.

b) A proposed male sterile system should have a wider restoration spectrum so that the probability of selecting superior hybrid combination is higher, secondly, the seed set of the restored hybrids should be high and stable and less have influenced by adverse environment.

c) Good floral structure and flowering habits. The CMS line should flower normally and the daily flowering time should synchronize well with that of the male parent. Its stigma should be well developed after flowering. The glume opening should last longer and have a wider angle.

Maintainer Line (B Line)

The maintainer line is a specific pollinator variety used to pollinate the CMS line and the progenies produced still show male sterility. Therefore, the role of B line is to multiply the CMS line. The major characteristics of a CMS line are determined by corresponding maintainer line. In fact, the CMS line and its corresponding maintainer line can be considered as twins. They are similar to each other in appearance, differing only in some characters.

Restorer Line (R Line)

The restorer line is a pollinator variety used for pollinating the CMS line to produce F1 hybrids that become normal in fertility and thus can produce seeds by selfing. As an elite restorer line, it should have:

a) Strong restoring ability. That is, the seed set of its F1 hybrids should be equivalent to that of a normal variety.
b) Good agronomic characteristics and combining ability.
c) Well-developed anthers with heavy pollen load, good flowering habits and normal dehiscence.

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Most of the male sterile line used in commercial production nowadays belongs to CMS or three -line system. In this system, the male sterility is controlled by both cytoplasm and nucleus. That is, the interaction between the sterile genes in the cytoplasm and recessive sterile genes in the nucleus. However, the dominant nuclear gene, R, can restore fertility in the F1 hybrid with male sterile cytoplasm. The genetic constitution and the relationships between the A, B and R lines are shown in Figure 3.

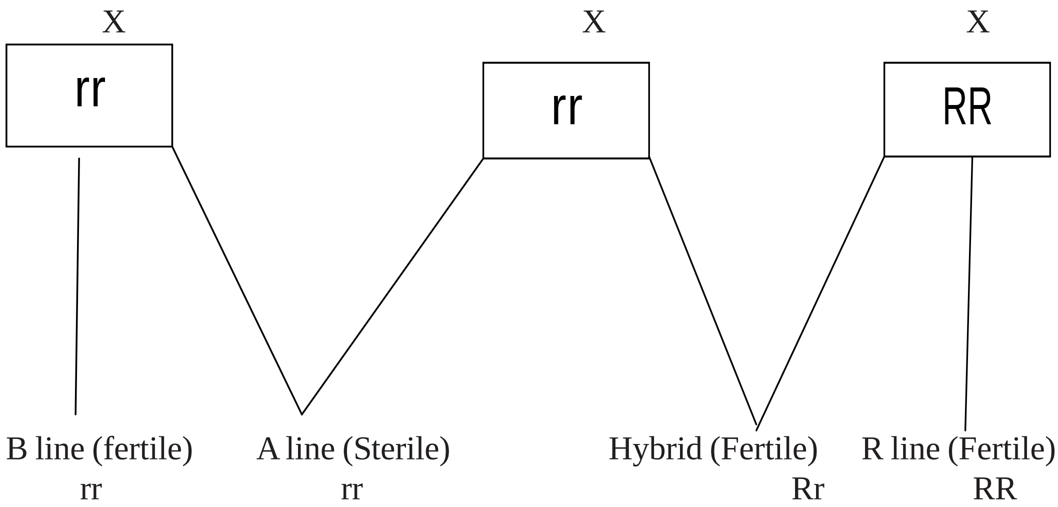

Figure 3: Schematic description of cytoplasm-genetic male sterility system.

The genotype of the CMS line, maintainer line, restorer line and F1 hybrid are S(rr), N(rr),N(RR)/S(RR) and S(Rr) respectively. Because the cytoplasm only comes from the female parent, the progenies of A/B are of S(rr) genotype, which is the same as the CMS line and they exhibit male sterility accordingly. In the cross of A/R their F1 progeny is S(Rr). Since the restoring gene is dominant, fertility is recovered in F1 plants.

Photo-and thermo-sensitive genetic male sterility (PTGMS) – two line system

In 1980s, China has successfully developed two new kinds of rice genetic tools, which are: photoperiod-sensitive genetic male sterility (PGMS) and thermo-sensitive genetic male sterility (TGMS) lines. Their fertility/sterility alteration is induced by day length and temperature, thus the line with such characteristics is generally called photo and/or thermo-sensitive genetic male sterility (PTGMS) line. The PGMS and TGMS lines are foundation for developing two-line hybrid rice (Figure 4).

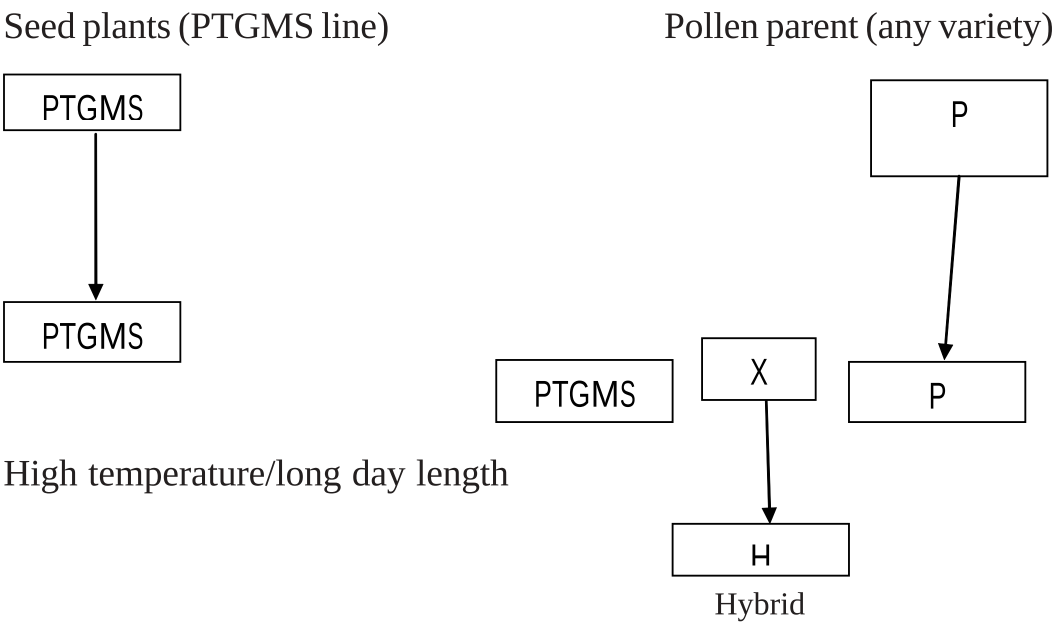

Figure 4 Schematic description of the use of PTGMS Lines for developing two-line hybrids

Characteristics of PTGMS lines.

In 1973, a rice plant which became male sterile under long day length and resume fertility under a short day length was discovered in China. It was a spontaneous mutant of a japonica variety, Nongken 58 and was called PGMS rice. On the other hand, Fertility/sterility alteration of TGMS lines is induced mainly by temperature. The existing TGMS lines become completely male sterile under high temperature. The day length has very little influence on fertility.

Advantages of two-line system hybrid

Exploitation of PTGMS lines to develop hybrid rice has the following advantages over the classical three-line or CMS system:

1. It can simplify the hybrid seed production process and decrease the cost of hybrid seeds, since the B line is not needed. The PGMS lines under a

longer day length and the TGMS lines under higher temperature, show complete pollen sterility, thus they can be used for hybrid seed production in these conditions. Under a shorter day length or moderate temperature conditions, they show almost normal fertility and thus can multiply themselves by selfing.

2. Since male sterility are controlled by recessive genes in PGMS and TGMS lines, nearly all common rice varieties can easily restore the fertility of such MS line. Therefore, the choice of parents is greatly broadened and as a result, the probability of developing superior hybrid is increased.
3. PGMS and TGMS genes can be easily transferred to almost any rice cultivars to develop new PTGMS lines for various breeding purposes.
4. Male sterility in PTGMS lines has no relation with the cytoplasm and the unitary cytoplasm situation of WA types can be avoided.

Procedure for breeding hybrid rice variety (three-line system)

Source Nursery

Depending on the breeding objectives, various three line materials and germplasm resources with different agronomic and biological characteristics are collected and planted for crossing and test crossing. The CMS lines and their maintainer lines should be grown in isolated plots. The other germplasm materials are each planted with 10 to 20 plants and one seedling per hill in the plot. In order to attain synchronization of flowering, certain materials are to be seeded at different time or treat with short day length.

Testcross

The objective of the testcrossing is to identify the fertility of F1 hybrids and screen the restorer lines and maintainer lines. Usually 20 plants are grown in one or two rows for each cross combination. A check variety is planted after every 10 to 20 hybrid combinations. If the F1 of a certain combination shows male sterility and its male parent is acceptable to the breeding objective with respect to its agronomic traits, this male parent could be used to develop a CMS line by successive backcrosses. When the F1 of a certain combination is normally restored in fertility and has good characteristics, its male parent could be a restorer line through re testcrossing with the original CMS line. Those F1s whose male parents have poor restoring or maintaining abilities are generally discarded.

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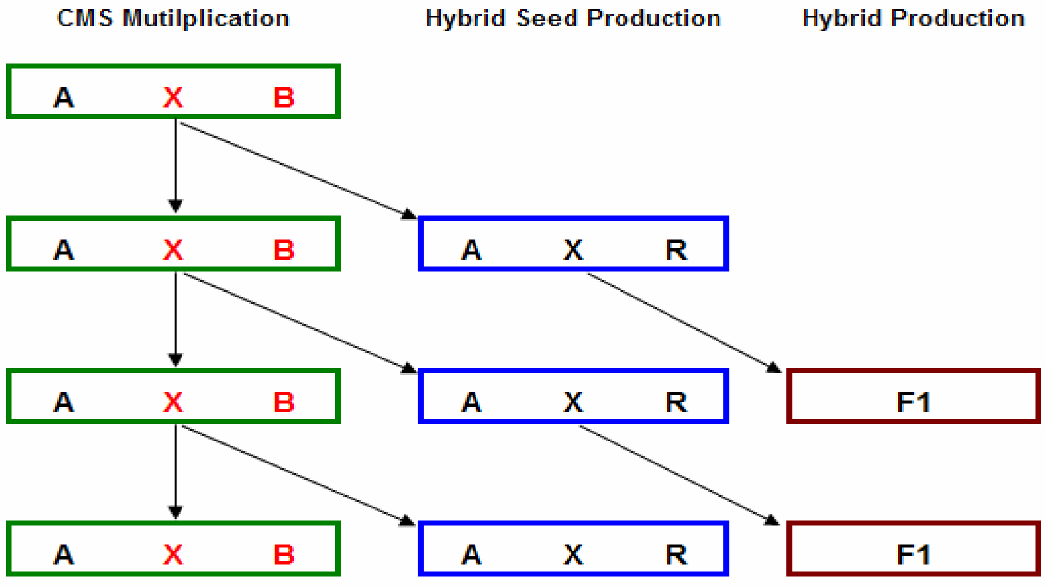
Re-testcross Nursery

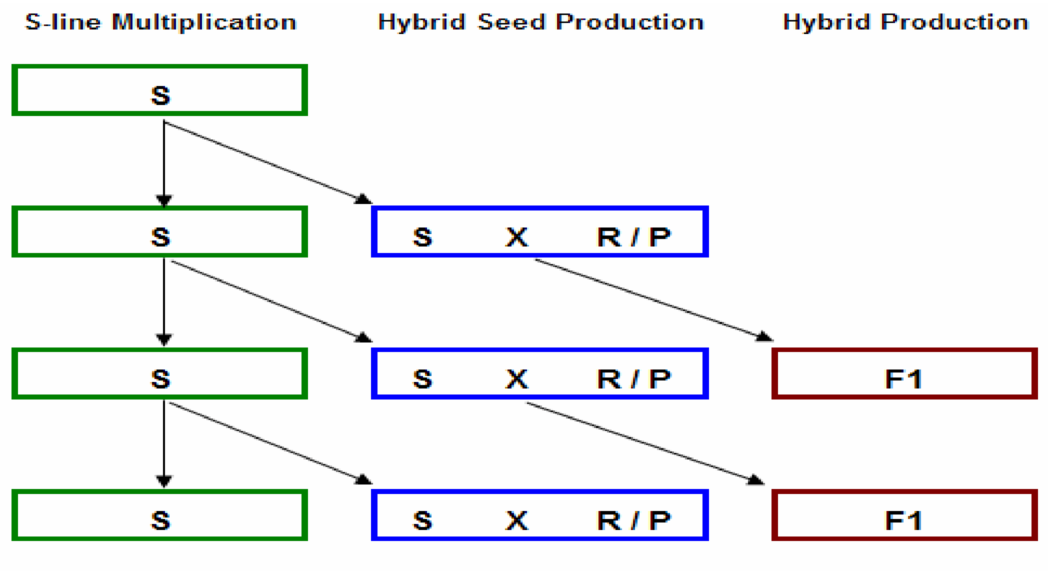
To identify the restoring ability of the male parent again, in the re=testcross nursery about 100 plants are grown for each combination, along with a standard commercial check variety. A preliminary observation of the heterosis in the F1 is made in this nursery. If the given F1 is again normal in seed set, then its male parent is confirmed to be a restorer line. If the F1 simultaneously exhibits heterosis, this combination can be put into the next stage for further test.

Backcross nursery

To develop an excellent CMS line and its corresponding maintainer line, the sterile hybrid plants and the recurrent male plants should be grown in pairs in the backcross nursery. Successive backcrosses should be carried out for four to six generations, depending on breeder's experiences and the distance of relation between the parents. The most important point in the course of backcrossing is to select those completely sterile plants whose characteristics are inclining or similar to the recurrent parent. When the backcross progenies are stable in sterility and apparently conform to the characteristics of the male parent under a population of over 1000 plants, these progenies are designated as a CMS line. The corresponding male parent used as the recurrent parent is designated as a maintainer line.



Three-Line Hybrid Rice Production



Two-Line Hybrid Rice Production

Heterosis evaluation

1. *Nursery for evaluating combining ability*

Hybrid combinations made from crosses between various CMS and restore lines should be planted in the combining ability evaluation nursery so that the best CMS and restorer lines with a good combining ability as well as hybrid combinations may be selected. Each combination is planted in three replications plots with about 300-500 single seedling plants per plot. A standard commercial variety or a leading rice hybrid is used as a control.

2. *Replicated yield trial*

The selected promising combinations are compared with each other in the replicated yield trial. In this trial, three or four replications should be adopted and the plot size should be more than 20 m^2. A standard commercial or leading hybrid variety is used as a control. The trial is usually conducted for one or two years. Based on visual observations and analysis of their agronomic characteristics as well as grain yield, grain quality and disease and insect resistance, the best combinations will be recommended for regional trial.

3. *Regional trial*

The promising hybrids recommended are put in the regional trial to determine their high yielding potential and adaptability to different environments. The planting design is similar to that of replicated yield trial, but the regional trial should be strictly carried out according to standard regulations. During the regional trial, the farmer's field evaluation is generally carried out simultaneously.

CONCLUSION

Real food security can be restored in Nigeria, even though some factors still militate against the restoration, including insufficient production of food and fiber, inefficient policies and corruption, conflicts and civil insecurity, climate change and natural disasters, gender inequity, low use of technology and other inputs, inadequate attention to critical aspects of the value chain such as processing, handling and storage/preservation, amongst others. Rice is important staple food stuff in Nigeria and the mass production locally does not meet the demand, hence there is need to improve its production technology. With the introduction and adoption of three-lines hybrids technology the grain yield is expected to more than those of improved or high-yielding varieties of the same growth duration. Further developments and adoption of two-line hybrid technology may have yield advantages over those of the equivalent three-line hybrids.

REFERENCES

Abbas A. M., Agada I. G. and Kolade O. (2018). Impacts of Rice Importation on Nigeria's Economy. *Journal of Scientific Agriculture* 2, 71-75. doi: 10.25081/jsa.2018.v2.901.

Babu R. V., Shreya K, Kuldeep S. D., Usharani G. and Nagesh P(2012). Genetic Variability Studies for Qualitative and Quantitative traits in Popular Rice (*Oryza sativa* L.) Hybrids of India. *Int. J. Sci. & Res Pub*. 2(6), 1-12.

Biswash P. L., Ghosal S. Kamal H. and Ujjal K. N. (2010). Genetic variability, correlation and path analysis, in maintainer lines of hybrid rice (*Oryza sativa* L) Bangladesh. *J Prog. Sci. & Tech*. 8(1), 115-118

Food and Agricultural Organization (FAO) (1996), World Food Summit. Kano: Food and Agricultural Organization of United Nation

Fischer K. S, Lafitte R., Fukai S., Atlin G. and Hardy B. (editors) (2003). Breeding rice for drought prone environments. Los Baños (Philippines): International Rice Res Inst. 2003; 98 p.

Ghosal S. Syed MA, Mkhatun, Biswash PL and Aditya TL (2012), Evaluation of selection criteria in premium quality rice genotypes through genetic variability, character association and path analysis. Bangladesh Rice J. 16, 59-62.

Idris A. E., Justin F. J., Dagash Y. M., and Abual A. I. (2012). Genetic Variability and Interrelationship between Yield and Yield Components in Some Rice Genotypes. A. J. Exp. Agric. 2(2): 233-239.

Iftekharuddaula K. M., Hassan M. S., Islam M. J., Badshah M. A., Islam M. R. and Akhter K. (2001). Genetic evaluation and selection criteria of hybrids rice in irrigated ecosystem of Bangladesh. Pakistan J of Biol Sci.; 4(7): 790-792.

International Crop Science Congress, 26 Sep – 1 Oct 2004, Brisbane, Australia.

Khush G. S. and Aquino R. C. (1994), Breeding tropical japonicas for hybrid rice production. In: S. S. Virmani (ed) Hybrid rice technology: New Developments and future prospects (pp. 33–36).

Kumar R., Krishnapal R., Mandal S. K., Ramashankar P. S. and Rai R. (1994). Genetic study of major characters in upland rice. *Environment and Ecology*, 12(2): 363-365.

Kumar R., Venuprasad R. and Atlin G. (2007). Genetic analysis of rain fed lowland rice drought tolerance under naturally occurring stress in eastern India: heritability and QTL effects. F Crop Res, 103:42-52.

Lafitte H. R., Ismail, A. Bennett J. Abiotic stress tolerance in rice for Asia: progress and the future in "New directions for a diverse planet". Proceedings of the 4th

Longping Yuan, Xiaojing Wu, Fuming Liao, Guohui Ma and Qius Heng xu (2015). Hybrid rice technology. China agricultural press, P.131

Narciso J and Hossain M (2002). World Rice Statistics. IRRI.; p 29

Nwachukwu, I. M., Agwu, N. M. and Ezeh, C. I. (2008). Comparative study of consumer purchase attitude of local and foreign rice in Abia State. Proceedings of 42nd meeting of Agricultural Society of Nigeria held at Ebonyi State University, Abakaliki, 19-23 October; pp. 764-767.

Sabu K. K, Abdullah M. Z, Lim L. S. and Wickneswari R. (2009). Analysis of heritability and genetic variability of agronomic important traits in Oryza sativa x O. rufipogon cross. Agron Res.; 7(1), 97-102

Sao A. (2002) "Studies on combining ability and heterosis in F1 rice hybrids using cytoplasmic male sterile lines," M. Sc. (Ag.) Thesis, IGAU, Raipur

Satya A. G., Kandasamy and Ramalingam J. Heterosis in hybrid rice (999), Crop Res, 18(2) 243-246.

Shivani D, Sree N and Reddy R. (2000), Variability, heritability and genetic advance for morphological and physiological traits in certain rice hybrids, Oryza, 37(3):231-233.

Turner N. C., Wright G. C., Siddique K. H. (2001). Adaptation of grain legumes 486 (pulses) to water limited environments, Adv. Agron.; 71, 123–231.

