Biosciences, Biotechnology Research Asia Vol. **6**(1), 75-79 (2009)

Molecular techniques: Prospects in crop enhancement, production, sustainance and improvement in a developing economy

J.P. MAIRIGA* and S.D. GYAR

*Department of Biochemistry & Molecular Biology, Nasarawa State University, Keffi, (Nigeria).
Department of Microbiology, Nasarawa State University, Keffi, (Nigeria).

(Received: December 12, 2008; Accepted: February 09, 2009)

ABSTRACT

Today there is a steady pace of advancements in efficacy, productivity and stability in plant breeding the World over. However, new approaches and knowledge are needed to permit feasible incorporation of desirable traits from exotic plants into mainstream crop improvement programs. Understanding the nature of genetic variations in traits is therefore an essential element in developing rational approaches for biochemical pathway modifications related to crop improvement just as novel diversity is needed for pest resistance, yield and enhanced kernel traits. This paper has attempted to address the role of molecular markers in crop improvement and production, outlining its roles in a developing economy. It also provides an overview of the techniques, applications and issues involved in the use of molecular markers for the improvement of domestic plant populations.

Key words: Molecular markers, crop improvement.

INTRODUCTION

Since ancient times, farmers and plant breeders alike have influenced the genetic characteristics of their crops by selectively saving seeds collected from high yielding, healthy, well adapted plants for use in the future planting circles, through rigorous selection methods that are extremely slow and highly unpredictable (Drecher, 2007). Without extensive new knowledge about genetic mechanisms, gene functions, levels of gene diversity, and the tools needed to manipulate them, enhancing crop improvement and production to meet the worlds' needs for feed and food grains would be impossible. New approaches and knowledge are therefore necessary to maintain a steady pace of advancement in efficiency, productivity, and stability of crops by possibly incorporating desirable traits from exotic crops into mainstream plant improvement programs. Novel advocacy is therefore necessary for pest resistance, yield, and enhanced kernel traits (Raune and Sonnino, 2007). Similarly, understanding the nature of genetic variation in traits is a key to developing rational approaches for biochemical pathway modifications needed for crop improvement.

The advent of science based selection strategies using Mendellian principles of inheritance has rapidly improved plant varieties especially in the last two decades (Haullauer, 2007). The adoption of the genes of interest in breeding programs and in superior cultivars that have the tendencies of meeting the food, feed, fuel, and fiber needs of the ever increasing world population and technological advancement of a nation cannot be over emphasized (Raune and Sonnino, 2007). Importantly, with the availability of large numbers of genetic markers for most species of interest, the effects and location of marker linked genes having some impact on a number of quantitative traits could be estimated using approaches that can be applied to dissect the genetic make-up of any physiological, morphological and behavioral traits in plants. The ultimate goal of plant breeders at all times, is to develop cultivars that are consistently of good performance for the primary traits of interest, and therefore though primary traits may vary among crop species overtime, the ultimate goal remains the same.

Definition and nature of molecular markers

Molecular Markers are identifiable DNA sequences, found at specific locations of the genome, and transmitted by the standard laws of inheritance from one generation to the next (Farreira, 2005). Markers are not normal genes as they usually do not have any biological effect; however, they rely on assay in contrast to morphological markers that are based on visible traits, and biochemical markers that are based on proteins produced by genes (Raune *and Sonnino,* 2007). Molecular Markers systems allow high density DNA marker maps with many markers of known location interspersed at short intervals through out the genome to be constructed for species, hence providing the conventional framework needed for application on various programs. Molecular Markers have formatted a revolution in the speed and quality of large scale plant germplasm characterization and the analysis of genetic traits important for crop improvement (Andersen & Lubberstedt, 2003).

Types of molecular markers

There are different types of Molecular Markers. Some of which are:

- Restriction Fragment Length Polymorphism (RFLPs).
- Random Amplification of Polymorphic DNAs(RAPDs)
- Amplified Fragment Length Polymorphisms (AFLPs).
- Microsatellites or simple Sequence repeats (SSRs).
- Single Nucleotide.

These Markers may differ in a variety of ways, based on their technical requirements (whether automated or required use of radioactivity), amount of time, money and labor needed, or number of genetic markers that can be detected through the genome (Statistical power), the amount of genetic variations that can be found at each marker in a given population and degree of polymorphism (Antonnio *et al,* 2004).

Benefits of molecular marker technology

Excitement about the advancement in molecular biology and its potential impact on agriculture emanated from scientist' ability to manipulate and control genes using newer approaches which might be seen from historical viewpoint and as part of the evolution of the science of genetics as postulated by Gregor Mendel in 1866 (Raune and Sonnino*,* 2007)

In order to appreciate the relevance of these techniques in using molecular markers over the conventional approach, it is pertinent to analyze the potential areas we may benefit from its application in crop improvement.

Molecular Markers are very useful for genetic analysis and manipulation of important agronomic traits. They are useful for the assessment of genetic diversity, selection of difficult traits, desirable genotypes, recombination and mapping of various interacting genes (Tuinstra *et al, 1997).* With ultimate goal in genetic analysis, molecular techniques using markers help in determining, analyzing and storing DNA sequenced information for a wide variety of applications (Sergio *and* Gianni,*,* 2005). Such markers are relevant in clarifying the genetic organization of the species and increasing the efficiency of breeding efforts (Menkir *et al, 1997). They also serve as tools in the genetic prediction o*f individuals' risk of diseases and development of herbicides based on appraisals towards targeting the molecular pathways of the disease and host. In addition, with marker maps, putative genes affecting traits of interest can be detected by testing for statistical associations between the marker variants and any trait of interest (Young, 1999).

Managing biodiversity does not only mean genetic characterization through DNA polymorphism detection, but requires information on issues of both in-situ and ex situ plant germplasm management, that may assist in decision making (Sergio and Gianni, *2005),* these same authors maintained that for ex-situ crop germplasm maintenance, molecular tools may contribute to the sampling, management and development of "Core" collections and utilization of genetic diversity.

But, for in-situ and on farm preservation strategies of genetic resources, molecular markers might help in the recognition of the most representative populations within the “gene pool” of a landrace.

The development of marker technologies has facilitated the subsequent cloning and characterization of disease, insect, and pest resistance genes from a variety of plant species (Quedraogo *et al, 2002).* Molecular marker techniques have the chances of increasing the screening efficiency of traits in breeding programs in a number of ways, some of which are;

- ability to screen in the juvenile stage for traits that are expressed late in the life of the organism e.g. the gain or fruit quality, male sterility, photoperiod sensitivity).
- ability to screen for traits that are extremely difficult, expensive or time consuming to score.
- ability to perform simultaneous marker assisted selection (MAS) for several characters at one time or to combine MAS with phenotypic or biochemical evaluation.
- ability to distinguish the homozygous from the heterozygous conditions of many loci in a single generation without the need for progeny testing as molecular markers is co-dominant.

Table 1: Number of research initiatives utilizing genetic markers in crop and forestry sectors sorted by type of markers

Markers	Crop	Forestry	Total
Rflp	61	09	70
Rapd	158	15	173
Ssrs/ microsatellites	68	19	87
Aflp	65	03	68
Isozymes	02	50	52
Chloroplast dna markers	0	11	11
Rdna	0	4	4
Others	135	77	212
Total	489	188	677

Source: Sonnino *et al,* 2007.

Overview of some uses of molecular markers in developing countries

Sonnino *et al*, (2007), posits that assessments relating to the use of Molecular Markers in crop Plants improvement in developing countries currently contains 677 entries from FAO-BioDEC and FAO country reports produced by National Agricultural Research Systems (NARS), which are related to the use of Molecular marker techniques. From these, 489 are associated with crop plants and 188 with forest trees. It is widely noted that early generation DNA based Molecular Markers such as RAPDs, are the most in use (Table 1). Intriguingly, only in five cases of these research initiatives have reached the final stage of development, giving rise to commercialized products (Table 2).

FAO-BioDEC includes 2336 entries related to crops and 829 related to forest tress. The data base currently covers 74 developing countries and shows that while research involving molecular markers in Africa is under way in only a few countries including Ethiopia, Nigeria, South Africa, and Zimbabwe, the crops understudied range from traditional commodities to tropical fruits.

Table 2: Number of research initiatves utilizing genetic markers in crop & forestry sectors according to the development stage of the technique or product

Markers	Crop	Forestry	Total
Experimental phase	344	179	523
Field tests	107	8	115
Commercal phase	4	1	5
Unspecified	34	0	34
Total	489	188	677

Source: - Dhalmini et al, (2005).

Whereas, in the near East and North Africa, it is reported for only six countries and these focus on the date palm, durum and bread wheat, rice, barley and olive trees (Guimaraes *et al*, 2006). Table 3, shows number of research initiatives utilizing genetic markers according to the crop of application where greater attention is on cereals and pseudo cereals, pulses, fruit trees, root and tubers.

Challenges on the application of molecular markers in developing countries

Major differences exist between regions and within regions regarding the application of molecular marker techniques in plant breeding, while some countries have developed quite extensive research programs, others particularly in Africa remain excluded from these advancements (Toenniessen *et al*, 2003)

These can be explained by the relative high investments in infrastructure and human resources necessary to undertake research in this field. Public plant breeding and biotechnology programs in developing countries are being eroded through lack of funding and this affects breeding continuity and objectivity (Sonnino *et al*, 2007).

Table 3: Number of research initiatives utilizing genetic markers according to the crop of application

Crop group	Number of projects
Cereals and pseudo-cereals	134
Pulses	54
Root and tubers	51
Fruit trees	53
Vegetables	29
Industrial crops	74
Fodder crops	16
Aromatics	5
Others or not specified	72
Total	489

Source:- guimaraes, *et al*, (2006).

Before now, most of the traits considered in both plants and animal genetic improvement programs were quantitative and controlled by many genes and or environmental factors, with the underlying genes having small effects on the phenotypes observed (such as yields and size of plants). But, with the advent of DNA marker technology, the idea of rapidly uncovering the loci controlling complex multigenic traits appeared to be a dream. Even though, this position still remains greatly unimproved in developing countries where such benefits lagged even further behind (Sonnino *et al,* 2007). This is in spite of the enormous potential benefits molecular techniques represent (Young *et al*, 1992). Such obvious limitations include

- lack of adequate information dissemination on current techniques.
- lack of established breeding programs for application of molecular techniques.
- inadequate and efficient procurement systems for research projects

The way forward

National approach

The development of a national biotechnological strategy that incorporates both the public and private sector is very necessary for the attainment of any meaningful result in crop improvement through new initiatives involving the use of molecular markers.

Training

For better and informed decisions, training and retraining programs are required in different strata to drive home the goals of molecular techniques; basically, courses for researchers, constant graduate and undergraduate training and courses, as well as post doc. fellowship programs will greatly enhance performance in biotechnological attributes.

Public and private sector collaboration

For a cooperate dimension towards innovative technological approach in sustainable crop production and improvement, a public private partnership is inevitable. This will not only require continued public sector investments from domestic and foreign resources but an innovative funding mechanism on the part of international agencies and private local sector organizations.

Intellectual property right

Developing countries should be able to weigh their benefits and costs of intellectual property rights in the promotion of biotechnology and frame their policies accordingly.

CONCLUSION

Molecular Markers are widely utilized in the plant production sector of the developing World; however the present uptake of the technology does not reflect their actual potentials. Never the less, applied plant breeding must continue to be the foundation for the application of useful molecular techniques. Using the right traits will build a strong linkage between genomics and plant breeding in order to produce new and better cultivars. It is however recommended that each technique be carefully assessed for its actual potential in improving the efficiency of plant breeding and production.

REFERENCES

1. Andersen, J. R. and Lubberstedt, T., Functional Markers in plants TRENDS in *plant-science.* **8**(11): 554-560 (2003).
2. Antonio, A. F., Luciana, L. B., Antomia M.M.B., Isaias, O.G., Anete, P. S., Comparison of RAPD, RFLP, AFLP and SSR marker for diversity studies in tropical maize inbred lines. *Genetics and Molecular Biology* **24**(4): (2004).
3. Dhalmini Z., Spillane C., Moss J.P., Raune, J. & Sonniino., A. Status of research and application of crop biotechnologies in developing countries: preliminary assessment: Food and Agriculture organization of the UN Rome. 50-64 (2005).
4. Drecher, K., Khairallah, M., Pandey, S., Is marker-assisted selection cost-effective compared to conventional plant breeding methods? The case of Quality Protein Maize: paper presented at Ravello,Italy 24-28 August (2007).
5. Guimares, E. P., Kueneman, E., & Carena, M.J., Assessment of national plant breeding and biotechnology capacity in Africa and recommendations for future capacity building. *Horticultural Science* **41**: 50-52 (2006).
6. Hallauer, A.R., History; contribution, and future of Quantitative genetics in plant breeding: Lessons from maize. *Plant Breeding Review.* **24**: 153-168 (2007).
7. Menkir, A., Glodsbroguht, P., and Ejeta, G., RAPD based assessment of genetic diversity in cultivated races of sorghum. *Crop science* **89**: 4251-4255 (1997).
8. Quedraogo J. F., Tignege, J., Timko, M. P., & Bellile, F., AFLP markers linked to resistance against striga gesneriodes race - in cowpea *Viginia unguiculata*. *Genome* **45**: 787-793 (2000).
9. Raune, J., and Sonnino, A., Marker-assisted selection as a tool for genetic improvement of crops, livestock, forestry and dish in developing countries an overview of the issues (2007).
10. Sergio, L., and Gianni, B., Molecular markers based analysis for crop germplasm preservation. The Role of Biotechnology. Villa gualion, Turin, Italy. 55-56 (2005).
11. Sonninno, A., Carena, MJ., Elcio, P.G., & Barbara, R., An assessment of the use Moleecular Markers in developing countries. Food and Agriculture organization of the UN Rome. 30-44 (2007).
12. Toenniessen G.P., O'Toole, J.C., & D e Vries, J., Advances in Plant biotechnology and its adoption in developing countries: *Curriculum Opinion in Plant Biology* **6**: 191-198 (2003).
13. Tuinstra, M.R., Grote, E.M., Glodsbrough, P.B., and Ejeta, G., Genetic analysis of post flowering drought tolerant and components grain development in sorghum, *Molecular Breeding*. **3**: 439-448 (1997).
14. Young, N.D., A cautiously optimistic vision for marker-Assisted breeding. *Molecular breeder.* **5**: 505-510.[ISI] (1999).