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Molecular Markers and Its Applications in Plant Breeding

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DNA-based molecular markers have proved as versatile tools and have found their own position in crop improvement. Several marker systems have been developed and are applied to a range of crop species. Molecular markers are mainly used in diversity analysis, parent selection, germplasm characterization, identification, genetic fingerprinting, genetic diagnostics, genome organization and phylogenic analysis. Since the proposition of the concept in 1980, various types of molecular markers such as RFLP, RAPD, AFLP, SSR, SNP among others have been developed. A remarkable and exciting progress has been made in DNA marker technology for crop improvement via marker-assisted selection (MAS). Amongst others, the microsatellite DNA marker has been the most widely used in plant breeding.

Introduction

Molecular marker is a piece of DNA sequence that is readily detected and whose inheritance can easily be monitored. Molecular markers are based on naturally occurring polymorphisms in the genome (i.e., base pair deletions, substitutions or additions). The majority of these molecular markers are developed either from genomic DNA libraries [e.g. RFLPs (Restriction fragment length polymorphisms) and SSRs (Simple sequence repeats)] or from random PCR amplification of genomic DNA [e.g. RAPD (Random amplification of polymorphic DNA)] or both [e.g. AFLP (Amplified fragment length polymorphism)]. The molecular markers can be classified into two broad categories: 1. Hybridization-based (RFLP) and 2. PCR-based [RAPD, AFLP, SSR, SNP (Single nucleotide polymorphism), EST (Expressed sequence tag) etc.]. Of these, microsatellite markers also known as simple sequence repeats (SSRs) are the most widely used due to simple Polymerase Chain Reaction (PCR) procedure, transferability across laboratories, genome-wide distribution and the high degree of information provided by large number of alleles per locus. Nowadays, SNPs are widely available in most of agriculturally important crops since the genome sequence of those crops is made available. A comparison of most commonly used marker systems is tabulated as follows:

Feature	RFLPs	RAPDs	AFLPs	SSRs	SNPs
DNA required (µg)	10	0.02	0.5-1.0	0.05	0.05
DNA quality	High	High	Moderate	Moderate	High
PCR-based	No	Yes	Yes	Yes	Yes
Number of polymorph loci analyzed	1.0-3.0	1.5-50	20-100	1.0-3.0	1.0
Ease of use	Not easy	Easy	Easy	Easy	Easy
Amenable to automation	Low	Moderate	Moderate	High	High
Reproducibility	High	Unreliable	High	High	High
Development cost	Low	Low	Moderate	High	High
Cost per analysis	High	Low	Moderate	Low	Low

(Source: https://www.isaaa.org/resources/publications/pocketk/document/Doc-Pocket%20K19.pdf)

Properties of Ideal DNA Markers

1. It should be highly polymorphic nature.

2. It should be co-dominant inheritance (determination of homozygous and heterozygous states of diploid organisms).
3. It should be frequently occur in genome.
4. It should be selective neutral and should not be affected by stage, sex or environment.
5. It should be easily available.
6. It should be easy and fast in assay and analysis.
7. It must be highly reproducible

It is extremely difficult to find a molecular marker which would meet all the above criteria. Depending on the type of study to be undertaken, a marker system can be identified to fulfil a few of the above characteristics (Weising *et al*., 1995).

Application of Molecular Markers in Plant Breeding

The use of molecular technique for detecting differences in the DNA of individual plants has many applications of value to crop improvement. Different types of molecular or DNA markers are being used for several purposes including germplasm characterization, characterization of transformants, genome organization studies, duplication in the germplasm collection and phylogenetic classification of germplasm. However, for plant breeding applications, SSRs and SNPs are the recommended markers of choice. Molecular markers in plant breeding are deployed extensively for the development of saturated genetic maps (genetic and physical) and to find out genes/QTLs (quantitative trait loci) controlling the traits of economic importance. Molecular markers are used in selecting desirable genotypes during the selection exercises such as recombination breeding and backcross breeding. Marker-assisted backcross breeding (MABC) is one of the approaches to improve the elite genotypes. In MABC, the process of markers closely linked with target traits used for the purpose of selecting desirable progenies is called as foreground selection. Simultaneously several unlinked markers used for recovering the recurrent parent genome is called as background selection. Marker-assisted selection will aid selecting target traits rapidly and reduce the selection cycles in breeding thus save a lot of time.

Reference

Weising K, Nybom H, Wolff K and Meyer W. 1995. DNA Fingerprinting in Plants and Fungi (ed. Arbor A.) CRC Press, Boca Raton, pp. 1–3.