GENOMICS IN AGRICULTURE: A GATE WAY TOWARD DEVELOPMENT

Abstract

Currently genomics in agriculture is playing important role in advancement of agriculture. Genomics is agricultural is application of technology to decipher plant genes which ultimately leads to development of new, specific varieties of crops having superior traits. Innovations in genomics contributing progress in crop developments by improving desirable traits in agriculture. Several promising traits include higher yield crop, stress tolerance and pest resistance. Speedy development of crops and livestock with improved traits has been obtained with the application of genomics in agriculture. With the increasing population demand for food is increasing thus to meet this increasing food demand there is a urgent need to focus on advanced technologies to enhance crop production. Advent of recent advanced technology including next-generation DNA sequencing, many vital crop genomes including cereals, tuber crops, vegetables have been sequenced. Application of genomics in the field of agriculture has been discussed in this current book chapter.

Keywords: Genomics, Agriculture, Next-generation DNA sequencing, Technology

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I. INTRODUCTION

In the present scenario, with the enhancing global population we need a drastic enhancement in food production in coming future. With rapid enhancement in global human population which is expected to reach 10 billions by 2050 global food security is one of the key challenge in the coming future (Arora, 2019). Suitable land for agriculture is also getting reduced at the same pace because of increasing urbanization as a result of increasing human population. Thus, farmers, breeders, scientist, researches has major challenge to produce more and more food. Methods like crossing and selection have been successfully used to improve the agronomic characters of cultivated crops including rice, wheat, maize, pulses and others. Application of genomics in agriculture is known as agri-genomics (Mishra and Pandey, 2021). Genomics has wide application in the field of agriculture and has wide potential to speed up the sustainable production and fighting with food hunger at international level. Advent of genomics in agriculture has opened up so many prospects to enhance agriculture production. Genomic technology can support farmers, breeders and researchers to decode genetic markers associated with desirable traits. Improvement in the quality and quantity of crop yields can be achieved with this advanced innovative technology. Lab to land application of genomics technology in crops like rice, wheat, pulse has resulted in major improvement in desirable traits which can also cope with drastic climate change. Genomics has also potential to minimize the number of trials and failures in scientific research. Decoding of genes associated with desirable traits in crops has wide prospects in bringing revolutionary change in the field of agriculture. Genomics assist in many ways to scientist for best utilization of genetic data to probe desirable features which can be ultimately transferred to another crop plants. Development of new improved trait such developing drought-sensitive crop more drought-tolerant using genomic assisted breeding programme (Thudi *et al.*, 2014). Considering application and future prospects of genomics in agriculture the present book chapter outlines the agri-genomics that is application of genomics in agriculture. Various genomic based methods with wide application in agriculture enlisted in Table1.

Table1: Genomics based approaches having prospects in the transformation of agriculture

Sl.No.	Approaches	Application	Reference
1	Genomic selection	Exploitation of molecular genetic markers to design novel breeding programmes.	Jannink *et al.*, 2010
2	Genome Wide Association Mapping (GWAS)	Identification of genes associated with a particular disease (or another trait).	Uffelmann *et al.*, 2021
3	RNA-Seq/ Transcriptome shotgun sequencing	Time and tissue specific quantification of RNA	Yadav *et al.*, 2022
4	Microarray	Powerful tool to identify nucleic acid with mutation or transformation	Shalini *et al.*, 2018
5	Next-generation sequencing (NGS)	Sequencing of DNA/RNA and identification of mutation and variantsin it	Begum and Banerje, 2021
6	Genome editing	Editing of target genes to improve crop nutritional value	Friedrichs *et al.*, 2019

II. CHRONICLE OF GENOMICS

1. **Timeline:** Major developments depicting history of genomics and genetics research is displayed in Table2. Right from the discovery of DNA and sequencing of corona genes, all events are given here.

Table2: Timeline of History of genomics

Sl No.	Year	Discoveries
1.	1871	Friedrich Miescher reported presence of 'nuclein'
2.	1904	Chromosome theory of heredity was proposed by Walter Sutton and Theodor Boveri
3.	1910	First Nobel Prize in Physiology or Medicine is awarded to Albrecht Kossel for the discovery of the five nucleotide bases, adenine, cytosine, guanine, thymine and uracil.
4.	1950	Erwin Chargaff reported pairing pattern of the bases A, C, G and T.
5.	1952	Alfred Hershey and Martha Chase demonstrated that DNA carries genetic information.
6.	1953	Double helix DNA structure was reported by James Watson and Francis Crick.
7.	1961	"Code for life" that is "codon" decoded by Marshall Nirenberg, Har Gobind Khorana and colleagues, crack the 'code for life'.
8.	1968	Nobel Prize for Physiology and Medicine was given to Marshall Nirenberg, Har Gobind Khorana and Robert Holley for reporting the genetic code.
9.	1977	Frederick Sanger develops a DNA sequencing technique.
10.	1983	Kary Mullis developed and reported polymerase chain reaction (PCR).
11.	1985	Alec Jeffreys discovered DNA fingerprinting.
12.	1990	Human Genome Project is launched.
13.	1995	First bacterium genome sequence is completed (*Haemophilus influenza*).
14.	1999	First human chromosome22 is sequenced.
15	2000	The first plant genome of *Arabidopsis thaliana* and full genome sequence of the model organism *Drosophila melanogaster* (fruit fly) was sequenced.
16.	2001	First draft of the human genome sequence was announced.
17.	2003	Human Genome Project is completed.
18.	2005	*Oryza sativa* (rice) genome was sequenced.
19.	2007	A NGS technology was introduced.
20.	2008	1,000 Genomes Project was launched.
21.	2020	The genome of the SARS-CoV-2 virus is sequenced.

2. **Driving Discoveries**: in Agrigenomics Emergence of agri-genomics is one of the biggest revolutions in the field of agriculture bringing rapid enhancement in the field of molecular breeding. Genomic assisted breeding program such as marker assisted selection, genomic selection enabled development of more suitable and adaptable varieties in the field of agriculture. Several technological developments have fueled the breakthrough of agri-genomics. Range of methods including next generation sequencing (NGS) and microarrays for genotyping and single nucleotide polymorphism (SNP) analysis (Bohra et al., 2020). Rapid progress in NGS technology have resulted a drastic

revolution to develop varieties of plant crops with superior and desirable traits such as abiotic and biotic stress tolerance and climate smart crops.

III. METHODS FOR PLANT GENOMICS

1. **Next Generation Sequencing (NGS):** Next generation Sequencing (NGS) provides a powerful tool for discovery of domestication genes in crop plants and their wild relatives. The accelerated domestication of new plant species as crops may be facilitated by this knowledge (Boers et al., 2019). Major developments in the NGS technology have been depicted in Table2.

Table2: Key progress in the field of NGS

S.No.	Year	Development in NGS technology	Reference
1.	**2000**	The first of the NGS technologies i.e. Massively parallel signature sequencing (MPSS) has been launched by Lynx Therapeutics Company and it was later bought by Illumina.	Schuster, S.C., 2008.
2.	**2004**	The Roche GS20 i.e. new generation pyro-sequencing technology, the first NGS platform was marketed by 454 Life Sciences.	Schuster, S.C., 2008
3.	**2008**	The first paper about studying the human genome sequence using NGS was published.	Schuster, S.C., 2008
4.	**2014**	Illumina launched a new technology, called HiSeq X Ten Sequencer, and claimed to have produced the first $1,000 genome.	Van Dijk *et al* 2014

2. **Whole Genome Sequencing**: Whole-genome de novo sequencing is used to study and understand novel species (Hamilton and Buell, 2012). Resequencing can be used to probe and discover SNPs and structural variants. This technology facilitate comparative genomic analyses and improving breeding and selection.

3. **Epigenomics:** This advanced technology has been applied in agriculture to discover adaptive responses in plants with respect to changing environment. Major use of this technique is to detect changes in DNA methylation, chromatin structure and RNA expression (Alvarez-Venegas et al., 2019).

4. **Transcriptome Sequencing:** The study of gene expression dynamics in organisms has been revolutionized via RNA sequencing. Wide application of this technology is that it provides insight in to key molecules and mechanisms in development and during disease and stress conditions. Gene function can be understood in a much better and best way (Hao et al., 2012).

5. **Targeted Sequencing**: Targeted sequencing with a focus on the exome or specific genes can be used for the identification of common and rare variants such as SNPs and CNVs. These variants can help inform breeding decisions and reveal causative mutations for parasite susceptibility or disease (Barba et al., 2014).

6. **SNP Genotyping**: SNP genotyping by sequencing or microarray enables the whole-genome SNP profiling. SNP genotyping has been shown to work for GWAS, marker-

assisted selction/ breeding, marker-assisted backcrossing, QTL screening, and trait mapping (Jenkins and Gibson, 2002).

7. **Metagenomics**: Metagenomics enables researchers to identify microbial populations associated with animal and plant development, detect known and novel pathogens in animal populations, enhance animal digestion, and improve plant health via analysis of root-associated bacteria (Hugenholtz and Tyson, 2008).

IV. APPLICATION OF GENOMICS IN AGRICULTURE

1. **Agri-genomics transforming future of agriculture:** Agri-genomics is the application of genomics in agriculture, with a focus on plants, animals, and ubiquitous microorganisms (Mishra and Pandey, 2021). Agri-genomic technology is transforming traditional approaches to breeding of commercial species and monitoring and protection of wild populations. The main methods for agri-genomics are next-generation sequencing (NGS), microarrays, and polymerase chain reaction (PCR). Agri-genomics aims to find innovative solutions for protection and sustainable productivity for the food industry, and may provide insight into energy production or drug discovery. Genomic technologies are able to depict all the genes in a genome and their functions and manipulations of genes linked to specific phenotypic traits.

2. **Major Applications**

   - **Crop improvement**- Genomics is a favorable tool to face the major issue of increasing crop yields and livestock productivity to achieve zero hunger goals. Identification of genes associated with desirable traits can be achieved using crop genomic information. Recent advanced gene editing technologies including CRISPR/Cas9 can be used to target genes promoting desirable traits like biotic and abiotic resistance.
   - **Crop adaptation**- Adaptation of crops to changing environmental condition is one of the major need of the hour. Genomics in agriculture provides better platform to improve crop adaptation. Various NGS tools can be used to identify wild relative genes representing major reservoir of adaptation to extreme harsh climate change.
   - **Development of bio-products**- development and commercialization of bio-products can be achieved using NGS technology.
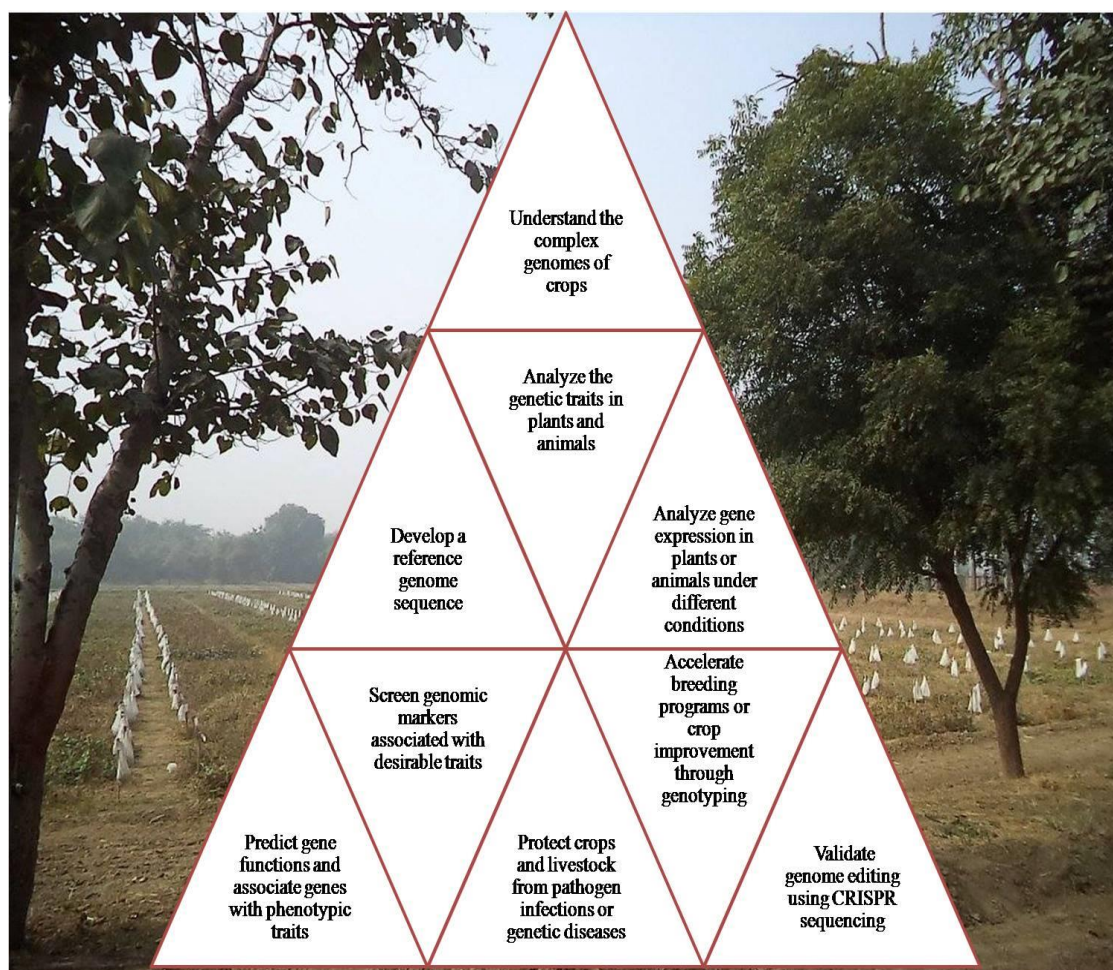
Figure1: Various aspects of agri-genomics

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