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Genetic Variability and it is Implication in Crop Improvement - A Review

Girma Ashe Ijara*

Ethiopia Institute of Agricultural Research, Debre Zeit Agricultural Research, Bishoftu, P.O. Box 2003, Addis Ababa, Ethiopia

**Corresponding author*

Abstract

Genetic diversity is degree of differentiation between or within species. Genetic variation is a measure of the genetic differences that exist within a population. Variation in crop plant can come either from environment or genetic difference. Genetic variability is the occurrence of variation among individual, due the difference in genetic composition. Variability is pre-request for crop improvement in plant breeding. Without variation among individual or species no need of crop improvement. The paper, therefore, aims to reviewing the overview of genetic variability and it is implication in crop improvement. Variation in crop plant can either due to genetic or environmental variation. There are different method of creating variability in crop for breeding purpose like, genetic recombination, mutation, ploidy modification, transposable element, gene transfer and soma-clonal variation. Genetic variation is important in natural selection that allows for increase or decrease in frequency of population. The existence of variation in crop plant enable individual to adapt new or changing environment. Variation in crop plant also important for adaptation of individual to changing or new environment, yield improvement and development of disease resistance. Therefore exploiting available genetic variation in crop plant or creating variation is corner stone for plant breeding program.

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Introduction

The genetic diversity of the population is fundamentally what drives crop plant evolution, whether it is occurring naturally or as result of human interventions. Diversity is the level of variation between or within species. The existing intra and inter-specific difference provides the basis of all crop improvement initiatives. There would have been no possibility for improvement in plant performance of various traits if every individual in the species had been exactly identical. Planning a successful breeding program will require careful consideration of the variability of the traits and their relationships to other parameters that affect crop yield (Mary and Gopalan, 2006). By estimating the genotypic and phenotypic coefficients of variation, comparative variability of traits can be assessed (Ahmad *et al.,* 2011). The heterogeneity found in germplasm is attributed to both heritable genetic influences and non-heritable environmental factors, according to Sami (*et al.,* 2013). While PCV expresses both the genetic and environmental influences on the trait, GCV only expresses the heritable component of the trait (Senbetay and Belete, 2020).

It is possible to identify genetic variation at both molecular and gross morphological levels. Plant breeders can analyses the genetic variability of their materials at the molecular level by using some biotechnological technologies (such DNA markers). Some of compositional or chemical traits, such as the protein content or sugar content of a plant component, require different tests or devices to be evaluated, while some genetic variation manifests itself as apparent variation in morphological traits (e.g., height, color, size) (Acquaah, 2004).

Plant breeding is a discipline for targeted and continuous development of new plant varieties. It utilizes the genetic variation between individuals within a plant species and combines the desired properties into new and improved varieties. Plant breeding is dependent on genetic variation, and new variation is fundamentally important for introduction of new traits in breeding programs. However, in cases where a specific genetic trait is not immediately available to be crossed into breeding materials, the genetic variation in a crop species can be expanded by other means (Holme *et al.,* 2019). In order to progress rapid and efficient crop improvement through plant breeding there should be genetic variability because superior genotypes can be selected from different population. The papers, therefore aim to reviewing the overview of genetic variability and it is implication in crop improvement.

Type of variation in crop

Environmental variation

Due to the non-uniform environment, plants growing in the field will have variations in the expression of several traits. The effects of the environment are not inherited. It may, however, affect heritable variation. Plant breeders want to be able to choose a plant based on its genetics (nature) rather than its environment (nurture) of growth. In order to achieve this goal, evaluations of breeding material are carried out as uniformly environment as possible. Additionally, the selection environment frequently resembles the environment in which the crop is grown for commercial purposes (Acquaah, 2004).

Genetic variability

Genetic or heritable variation is defined as variation that can be attributed to genes that encode particular traits and can be transmitted from one generation to the next. Generation after generation, heritable variability is consistently expressed. A mutation, however, has the power to fundamentally change an original expression (Acquaah, 2004). According to Allard (1960), genetic variability is the occurrence of variation among individuals due to differences in their genetic make-up or environment of upbringing. Falconer and Mackay's (1996) also define genetic variability as the tendency of individual genotypes within a population to differ for certain traits of interest.

Genotypic variability is a component of variation that results from genotypic differences among individuals within a population (Singh, 2001). Genetic variations of particular trait are interest to plant breeders since it has remarkable impact on the performance of the crop. In order to develop breeding techniques for crop improvement in the future, studies on genetic variability provide fundamental knowledge about genetic features of populations (Khleshtkina *et al.,* 2004). In order to determine how much genetic variation is there in the genotypes, components of genetic parameters like genotypic coefficient of variation and phenotypic coefficient of variation have a greatest significance.

Method of creating variability in crop

Genetic recombination

Meiosis is the sort of cell division that generates gametes, when genetic recombination takes place. Homologous chromosomes join up and form a structure known as a tetrad during this process. The chromosomes can then crossover and exchange genetic material, creating novel allele combinations. It only applies to species that reproduce sexually and serves as those species' main source of variation for plant breeders (Acquaah, 2004).

Genetic recombination is a greatly complex process. It involves the alignment of two homologous DNA strands (the requirement for homology suggests that this occurs through complementary base-pairing, but this has not been definitively shown), precise breakage of each strand, exchange between the strands, and sealing of the resulting recombined molecules. Both eukaryotic and prokaryotic cells experience this process with high precision and regularity (Clancy, 2008).

Consider a cross between two parents having different genotypes AAbb and aaBB. A cross between them will generate an F1 of genotype AaBb. In the F2 segregating population, and according to Mendel’s law, the gametes (AB, Ab, aB, and ab) will mix to form variability, some of which will be old (like the parents – parental), while others will be new (unlike the parents – recombinants)

Ploidy modification

Ploidy modification refers to only changes in the number of chromosome sets, i.e., not single chromosomes. We use the term 'genome instability' to refer to an increased frequency of mutations, agnostic of mechanism, typically involving an increased rate of chromosome gain or loss.

Natural changes in chromosomal number due to hybridization (between genotypes that are not identical) or irregularities in the nuclear division processes (spindle malfunction) may result in the emergence of new variability.

Incorrect chromosome numbers transferred to cells, such as polyploidy (individuals with multiples of the basic set of chromosomes for the species in their cell), can result from the spindle process failing during karyo-kinesis or even before that.

Aneuploidy is the term for when plants are created with multiple copies of just some chromosomes or deficits of other chromosomes rather than changes affecting entire sets of chromosomes. Sometimes, plants are produced with half the number of chromosomes in the somatic cells (called haploids) (Acquaah, 2004).

Mutation

Mutation is any change in the DNA sequence of a cell. Both exposure to environmental DNA-damaging chemicals and mistakes made during cell division can result in mutations. It is the main source of biological variation. They develop spontaneously in nature as a result of mistakes in cellular functions including DNA replication (or duplication) and chromosomal abnormalities (deletion, duplication, inversion, and translocation).

Plant breeders may also cause mutations using chemicals and radiation. Many beneficial mutations, such as dwarfs and nutritional quality genes, have been discovered in nature or created by plant breeders. They persist in the population in the heterozygous state as recessive alleles and become expressed only when in the homozygous state, following an event such as selfing (Acquaah, 2004).

Transposable element

Transposable elements are defined as DNA sequences that are able to move from one location to another in the genome. Transposable elements have been identified in all organisms, prokaryotic and eukaryotic, and can occupy a high proportion of a species genome. The mobilization of transposable elements is termed transposition or retro-transposition, depending on the nature of the intermediate used for mobilization.

Gene transfer

The most advanced method of gene transfer for creating genetic variability for plant breeding is rDNA technology. The DNA is universal, with a few tiny exceptions. Consequently, a plant may receive DNA from an animal. Genes from distant sources may be incorporated using biotechnology methods into adaptable cultivars (Acquaah, 2004).

Variation in biological traits is a result of the natural process of gene transfer from a living thing to another. Gene transfer in plants, also known as plant transformation, depends on the effective integration of foreign DNA into the target plant cells as well as the subsequent growth of a full plant from the transformed cells. Plant transformation methods therefore require an efficient way to introduce DNA into cell and the regeneration of the transformed cells or tissues into whole plants.

The transfer of genes from the nucleus and cytoplasm occurs in plants through protoplast fusion. Although the fusion product must be backcrossed to the recipient line for several generations to establish a new, stable line and the desired form from the donor must be present in this line for the fusion to be successful.

Fusion joins the genomes of two parents, just like traditional breeding, however results are often acquired more quickly. Protoplast fusion can be used for transferring genes that are hard to identify, isolate, and clone or for polygenic traits. Furthermore, protoplast fusion can be used for plants that cannot be crossed sexually (although plants regenerated from such fused hybrids may sometimes be sterile) (NRC, 1987).

Soma-clonal variation

Soma-clonal variation is the variation seen in plants that have been produced by plant tissue culture. Chromosomal re-arrangements are an important source of this variation. Soma-clonal variation is not restricted to, but is particularly common in, plants regenerated from callus.

Scale of variation

Quantitative Variation

Quantitative traits are measurable phenotypic traits of degree, such as height, weight, skin color, susceptible to pathological disease or intelligence in human, the quantity of flowers, fruits, seeds, milk or eggs produced by plants or animal. These traits are economically significant phenotypic traits.

The quantitative traits are also called metric traits. They do not show clear cut difference between individual and form a spectrum of phenotypes which blend imperceptivity from one types to another genes (polygenic inheritance) with effect that are too small to be individual distinguished.

They are sometimes called minor gene. The variation in environmental condition that plants in the population are exposed to considerably alters how quantitative traits are expressed (Acquaah, 2004).

Qualitative Variation

Qualitative variation is simple to categorized, study and applies in breeding. It is simply inherited (regulated by one or a few genes) and can be studied using Mendelian genetics. The qualitative traits are the traditional Mendelian traits of kinds like form (round or wrinkled seeds of pea), structure (horned or hornless condition in cattle's), pigments (black or white coat of guinea pigs), antigens and antibodies (blood group types of people), and so on.

Fig.1 Five types of chromosomal mutation

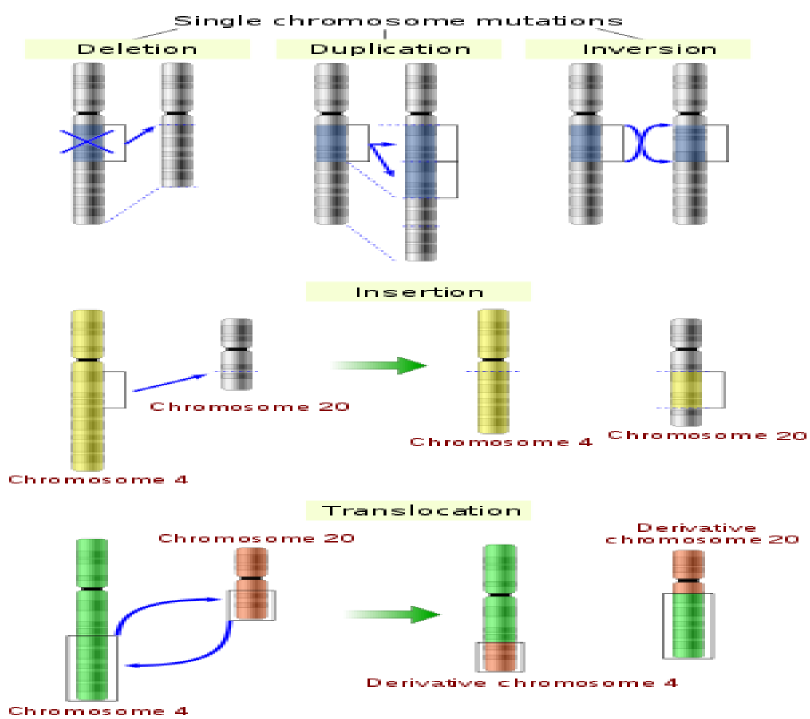
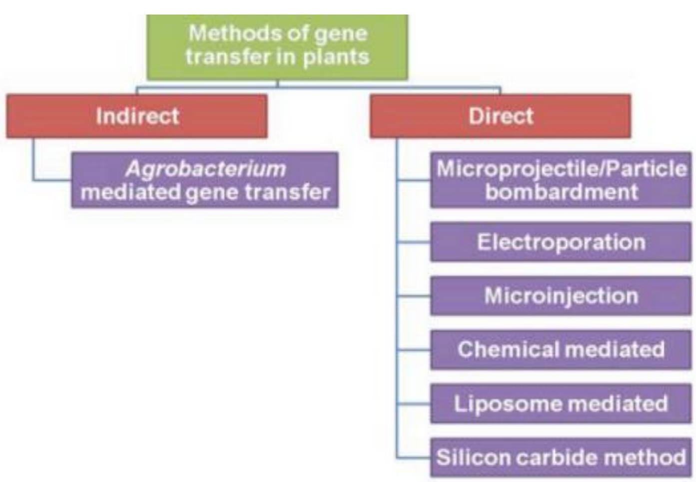


Fig.2 Method of gene transfer in plant



A single gene with two or more alleles may be responsible for a particular qualitative characteristic, and there may be little to no environmental interference with the gene's effects. It is believed that the organisms that exhibit qualitative traits belong to distinct (independent) phenotypic classes and show discontinuous variations (Acquaah, 2004).

Implication of genetic variability in crop improvement

Genetic variation is essential for natural selection because natural selection can only increase or decrease frequency of alleles that already exist in the population. A population benefits from it because it allows some individuals to adapt to their surroundings while still ensuring the population's survival. Genetic variability study for agronomic traits is a key component of the breeding program for boarding the genetic pool of crop (Singh, 2001).

Variation allows some individual within a population to adapt to the changing environment. A population with more genetic variability typically has more phenotypic variability since natural selection only affects phenotypes directly. New alleles can improve an organism's capacity for reproduction and survival, which helps to ensure the allele's survival in the population. Other novel alleles could be instantly harmful (for example, a malformed oxygen-carrying protein), and the organisms that contain these mutations will eventually become extinct. Neutral alleles are neither selected for nor against and usually remain in the population. The ability of some individual and, consequently, a population, to survive in spite of a changing environment is one of the benefits of genetic variability.

Resistance to disease pathotoxins, herbicides, high salt concentration, mineral toxicity, tolerance to environmental or chemical stress, and increased production of secondary metabolites are just a few of the traits that soma-clonal mutants can be selected during in vitro culture. In order to give plants disease and herbicide tolerance, economically advantageous gene transfers have been done from bacteria to plants. Roundup Ready1 cultivars (such as cotton and soybeans) and Bt product (such as maize with lepidopteran pest resistance) are the two types of genetically modified products that are most frequently seen on the market (Acquaah, 2004).

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