Chapter 1

Cytogenetics in Genetics and Plant Breeding

In most of its stages, plant breeding makes use of auxiliary scientific disciplines. One of these disciplines is genetics, with its subdisciplines quantitative genetics, population genetics, cytogenetics, molecular genetics, etc. To understand the role of cytogenetics in plant breeding, it is useful to first give a brief review of the segment of genetics it covers, and what it is considered to include.

1.1 Cytogenetics as a Subdiscipline of Genetics

1.1.1 The Two Functions of Genetic Material

The science of genetics studies the composition and functions of the “genetic material” (Fig. 1.1).

The “genetic material” has two essential functions: (1) to bring about and regulate biological processes, and (2) to maintain, multiply and adjust itself.

It is composed of different substances, the most fundamental of which is DNA. The two functions of the genetic material reflect the two basic functions of DNA: transcription and replication. Transcription is the first step in a series of interactive and thoroughly controlled processes that ultimately constitute the vital functions of all living material. It is the assemblage of RNA on the DNA which serves as a template, with RNA polymerases as enzymes. Only part of the DNA, the coding DNA, is transcribed. The coding DNA occurs in functional units of roughly 1000 base pairs: the genes. Transcription is followed by translation of segments of the thus formed m(messenger)-RNA into polypeptides. This occurs in special structures, the ribosomes, consisting of ribosomal RNA and proteins. The polypeptides are combined with other polypeptides and, if applicable, other compounds into a great variety of enzymes, regulatory substances and structural elements. The result is a highly complex, strictly regulated system of interacting processes and structures. This, the domain of gene action and gene expression, will not be considered here to any significant extent.
The second function of DNA, replication, is the first step in a series of highly regulated and interactive processes leading to systems of transmission of the genes from one generation of cells or individuals to the next, the domain of gene transmission. It involves interacting systems of structures and processes equally complex as the gene action and gene expression systems. Replication usually, although not without exception, involves all DNA of the nucleus and consequently results in complete duplication of the nuclear or organelle DNA with each round of replication. Usually, DNA replication of the nucleus is followed by nuclear and cell division leading to (somatic) growth and/or to multiplication.

The two functions of the genetic material (gene expression and gene transmission, Fig. 1.1) are biologically complementary and both necessary. The expression of a gene is of little consequence when it is not transmitted to a new generation. Life is finite, and without renewal by replication, the gene would be doomed to disappear. At first sight, replication and transmission seem to be of little use without function for the “genetic material”. Yet, in many higher organisms, the larger part of the DNA is without apparent function and still is faithfully replicated with its associated proteins, and trans-