Plants that fail to produce functional pollen grains are male sterile. Rice, being a self-pollinating crop, must involve use of an effective male sterility system to develop and produce F₁ hybrid varieties. Major male sterility systems used for hybrid rice breeding in China and elsewhere are cytoplasmic-genetic and chemically induced male sterility. Recently, photoperiod-sensitive and thermo-sensitive genetic male sterility systems are also being tested for their usability. Out of a total area of 15 million ha grown under hybrid rices in China, only about 10,000 ha are covered with hybrids developed by using chemically induced male sterility; the rest of the area is grown with hybrids involving cytoplasmic genetic male sterility and a fertility restoration system. Outside China, hybrid rice breeding programs are also deploying mainly the cytoplasmic genetic male sterility system. Use of photosensitive and thermo-sensitive genetic male sterility is still in an experimental stage. During 1990, some rice hybrids based on the photoperiod-sensitive genetic male sterility system were tested under farmers' field conditions in China (L. P. Yuan, pers. comm.). In this chapter, male sterility systems used in hybrid rice breeding are described and their relative significance discussed.

2.1 Cytoplasmic Genetic Male Sterility in Rice

The cytoplasmic genetic male sterility (CMS) system is controlled by the interaction of cytoplasmic and nuclear genes. Presence of homozygous recessive nuclear gene(s) for fertility restoration in association with sterility inducing genetic factor(s) in cytoplasm make a plant male sterile. The genetic factor(s) present in cytoplasm have been reported to be part of mitochondrial DNA (Levings and Pring 1976; Forde and Leaver 1980; Kadowaki et al. 1986). In the absence of a sterility-inducing genetic factor in the cytoplasm, plants become male fertile. In such a cytoplasm, if fertility restorer nuclear gene(s) are recessive, the plants will maintain sterility of the male sterile plants and such plants are designated as maintainers. If fertility restorer nuclear gene(s) present in an individual with or without sterility-inducing cytoplasm are dominant, the plant will restore fertility in a hybrid derived by crossing it with a CMS plant and such a plant is designated as restorer. Possible cytoplasmic-genetic constitutions of
plants, and their pollen fertility behavior and accepted designations are: S rfrf (sterile, CMS), N rfrf (fertile, maintainer), S/N RfRf (fertile, restorer) and S Rfrf (fertile, hybrid).

A cytoplasmic genetic male sterile line is maintained and multiplied by hybridizing it with an isonuclear maintainer line. Commercial F₁ hybrids are produced by crossing a cytoplasmic genetic male sterile line with appropriate restorers.

2.1.1 Sources of Cytoplasmic Genetic Male Sterility in Rice

The role of cytoplasm in causing male sterility in rice was first reported in 1954 (Sampath and Mohanty 1954). Later, Katsuo and Mizushima (1958) also observed a similar phenomenon in the progeny of the first backcross Oryza sativa f. spontanea/O. sativa cv. Fujisaka 5. Kitamura (1962a,b) observed slightly lower seed fertility in a hybrid involving a Philippine rice cultivar, Tadukan and a Japonica rice cultivar, Norin 8. Backcrossing with male parent Norin 8 increased spikelet sterility in the test progenies. Spikelet sterility was attributed to non-dehiscence of anthers, because both male and female gametes were normal. Sasahara and Katsuo (1965) studied cytoplasmic differences among rice varieties and developed a male sterile line by transferring the nuclear genotype of rice cultivar Fujisaka 5 in the cytoplasm of Chinese wild rice O. sativa f. spontanea. Shinjyo and Omura (1966a,b) also developed a cytoplasmic male sterile line in cultivated rice by substituting nuclear genes of a Japonica variety, Taichung 65, into the cytoplasm of Indica variety Chinsurah Boro II (Shinjyo 1969). Subsequently four more boro rice cultivars, viz., Assam Bhutaman, Chinsurah Boro I and Tepa, from India and Bangladesh were found to possess male sterile inducing cytoplasm (Shinjyo 1972b). Erickson (1969) and Carnahan et al. (1972) also reported development of CMS lines in Japonica rices from a cytoplasmic source of Indica variety Birco (PI 297120). Watanabe (1971) developed cytoplasmic genetic male sterile lines by means of Indica–Japonica crosses. Carnahan et al. (1972) developed a cytosterile line possessing O. glaberrima cytoplasm in a genetic background of the variety Colusa, in California, USA.

Athwal and Virmani (1972) developed a cytoplasmic male sterile line by substituting nuclear genes of Indica rice variety, Pankhari 203, into the cytoplasm of the semidwarf Indica variety, Taichung Native 1. However, this CMS line could not be used for breeding rice hybrids because of its instability, poor plant type, and photoperiod sensitivity. The first CMS line used to develop commercial F₁ rice hybrids was developed in China in 1973 from a male sterile plant occurring naturally in a population of wild rice (Oryza sativa f. spontanea) on Hainan island in 1970 (Yuan 1977). This plant was designated wild rice with aborted pollen (WA). Since then, a number of CMS lines have been developed in China and elsewhere from various wild and cultivated accessions (Lin and Yuan 1980; Virmani et al. 1986; Li and Zhu 1988; Virmani and Wan 1988). Male