Plant cultivation and breeding: Promise of technology

Symposium experts assess the prospects of some new techniques

by Alexander Micke

Biotechnology currently arouses a great deal of attention in developed as well as in developing countries. There are expectations of enormous economic gains, so nobody wants to stay behind. The primary focus of investment and work is on genetic manipulation of microorganisms that can be easily handled industrially to produce desired chemical compounds.

The continuous food shortages in parts of the world, however, also lead scientists to look at the possibilities of using new techniques to develop better varieties of crop plants. This aim has been successfully followed ever since man took up plant cultivation about 10 000 years ago. However, plant improvement is a never-ending task.

For more than 20 years, the United Nations Food and Agriculture Organization (FAO) and the IAEA – through their joint plant breeding and genetics section – have paid attention to the need for continuous improvement of crop cultivars. The basis for plant breeding is suitable genetic variability and mutation induction has been promoted as a way to create more variation for plant breeders, since not all desired genetic variants are found in nature or in ancient cultivars. Mutant germ plasm has successfully been used in at least 35 countries to develop better cultivars for agriculture and horticulture.* So it is already clear that induced mutants can profitably supplement natural and traditional germ plasm already held in breeders' collections and in so-called "gene banks".

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* See related article in *IAEA Bulletin*, Vol. 26, No. 2 (June 1984).

Somaclonal variation

In recent years, there have been reports that mutations also occur during *in vitro* culture of plant material without the application of ionizing radiation or other mutagens. Plant breeders reportedly could also use such mutations in their endless task to develop more productive varieties.

This "somaclonal variation", as it is called, and its potential value to the vast experience already accumulated in plant mutants obtained from radiation and chemical means, was a primary topic this past August at the FAO/IAEA Symposium on Nuclear Techniques and *In Vitro* Culture for Plant Improvement. The gathering was attended by 141 participants from 47 countries and international organizations.

Symposium experts concluded that the "somaclonal variation" derives from different nuclear as well as cytoplasmic disturbances, including chromosomal aberrations and aneuploidy (alterations in the number of chromosomes). However, the mechanisms by which these disturbances arise still are obscure. Provided that strong selection is applied, some of this variation could certainly be useful for plant breeding.

On the other hand, there appeared to be more worries about difficulties in maintaining genetic integrity under *in vitro* conditions, as opposed to euphoria about additional variation (which in any case could be obtained from experimental mutagenesis). Genetic integrity is necessary to make use of *in vitro* culture – for example, in virus-free propagation of potatoes, ornamentals, or fruit trees. It would also be essential for long-term preservation in "gene banks" of germ plasm that cannot be maintained in the form of seeds. Although it was

Mutation breeding by physical and chemical means has produced new, improved varieties of plants and crops worldwide, including the sorghum shown here in Venezuela's fields. (Credit: B. Donini, IAEA)

confirmed that *in vitro* culture for certain types of plants is genetically more stable than others, the problem is not easy to solve.

Accelerating plant breeding cycle

In vitro culture techniques also offer opportunities for acceleration of the plant breeding cycle, and accordingly the symposium reviewed how they could profitably be used in connection with mutation breeding using radiation or chemical mutagens. Several potential advantages were discussed: mutagens could be applied before or during culture. Mutant selection could be done during or after culture. Chimeras (plants having tissues with different genetic makeups) that arise from mutagen treatment of multicellular tissue could be dissolved by embryonic cultures derived from a single cell. Selected mutants could be quickly propagated by *in vitro* micropropagation for the required field performance testing.

Papers presented, however, indicated that considerable research is needed in many areas to derive benefits from the techniques for plant breeding programmes. In particular, this applies for *in vitro* mutagenesis and for *in vitro* mutant selection where only few traits are amenable and the relationships to field performance are dubious.* The most critical bottleneck, however, is the rather limited success in plant regeneration from single cells.

The promise of haploids

The same limiting factor applies to another very promising technology: the use of haploids, which are plants with a single instead of double chromosome set. Haploid plants can be derived from immature pollen grains by *in vitro* culture of anthers. The single chromosome set theoretically would allow easy recognition of gene expression and gene manipulation, including mutation induction. Subsequently, by chromosome doubling, normal but already homozygous diploid plants could be obtained for the development of cultivars. Unfortunately, for most crop plants the frequency of success in obtaining haploid embryos from anthers is very low — too low for reliable handling of breeding material.

Genetic engineering approaches

Turning to more fundamental issues, the symposium discussed a number of recent approaches of genetic engineering, such as protoplast (single cell) fusion aided by gamma radiation, micromanipulation, and transformation of plants using vectors. Particularly relevant from a plant breeding viewpoint should be the possibility of obtaining recombination of extranuclear DNA after protoplast fusion.

All these approaches are promising, but they will likely make only little contribution to plant breeding in the near future. The gaps in our knowledge of plant molecular genetics are startling, and several speakers pointed out that high research investments would be required to add new and efficient biotechnological tools to the mostly empirical plant breeding methods used today.

* See *Mutation Breeding for Disease Resistance Using In Vitro Culture Techniques,* IAEA-TECDOC-342 (1985).