PLANT BIOLOGY

# Twenty-first century crops

Jim Peacock

GENETIC engineering has great potential in agriculture. By the turn of the century we will be using crop products which have been honed to market specification by the addition, subtraction or modification of genes. Transgenes will also be important in increasing the efficiency of crop production systems, and an exciting example of what can be achieved is given by Mariani *et al.* in this issue (*Nature* **357**, 384–387; 1992). They report on the restoration of pollen fertility in plants which have a genetically engineered pollen sterility system. The experimental plant is oilseed rape (*Brassica napus*), an important crop species, but the system is likely to be a general one which will find use in many crop and horticultural species — including maize.

The hybrid maize seed industry is large and is successful because farmers are prepared to buy $F_1$ hybrid seed each year. The yield of the hybrid, relative to the inbred parental lines, justifies the extra cost of purchasing hybrid seed. Hybrid corn also outperforms open-pollinated corn, a cheaper but more variable alternative. Hybrids are used in a number of other 'broadacre' crops (sunflower, sorghum) and in horticultural species (cabbages, tomatoes) because in each case the hybrid is again superior to open-pollinated lines. Although we still do not understand the molecular basis of hybrid vigour (heterosis), its exploitation is arguably the single most important contribution of genetic research to agriculture.

In maize, hybrid seed is produced by controlled pollination of a pollen-sterile female line. The male sterility of the female line is generated by manual or machine removal of the tassel, the structure bearing the anthers in which pollen development takes place. Until the late 1960s, hybrid corn was produced without this expensive and labour-intensive process. Instead, sterility was generated by a genetically determined system; DNA segment rearrangement in the mitochondrial genome resulted in abnormal gene expression during pollen development, preventing the formation of fertile pollen grains. Unfortunately, rearrangement of the mitochondrial genome was also associated with another phenotype, susceptibility to southern leaf blight, caused by the fungus *Helminthosporium maydis*. The widespread destruction of crops by this disease resulted in the disuse of the cytoplasmic male sterility system, and the consequent adoption of mechanical removal of the tassel.

For years geneticists have searched without success for an alternative cytoplasmic male sterility system, or have attempted to develop nuclear gene systems. Now, genetic engineering has delivered a promising approach. Two years ago, Mariani *et al.* (*Nature* **347**, 737–741; 1990) described the consequences of introducing, into oilseed rape, a gene construct which coupled an anther-specific promoter to a bacterial coding sequence for a ribonuclease. This resulted in a spectacular, and specific, prevention of normal pollen development — the transgenic plant became male sterile. The promoter was from the *TA29* gene of tobacco, a gene expressed only in the tapetal cell layer of the developing anther. The ribonuclease, encoded by the *barnase* gene of *Bacillus amyloliquefaciens*, was cytotoxic, killing the tapetal cells and thus preventing pollen development.

This example of creative genetic engineering was particularly attractive because there was the possibility that a further component of the *Bacillus* ribonuclease system could be put to good effect. In *Bacillus*, the ribonuclease is active extracellularly and the bacterium itself is protected by a protein coded by the *barstar* locus. The *barstar* product complexes with the ribonuclease and disables it.

In transgenic plants the *barstar* product, produced under instruction of the same *TA29* promoter, complexes with the coexpressed barnase molecule, neutralizing its cytotoxic properties and normal pollen development ensues. Mariani *et al.* now document the protein–protein interaction at genetic and cellular levels. A plant with the *barnase* gene is pollen sterile; a plant with the *barnase* and *barstar* genes is pollen fertile. Both genotypes are needed for the crossing system, thereby providing for the regular production of hybrid seed.

Here we have the powerful and novel heterologous application of a gene system, one which is exquisitely developed in the bacterial donor. Like it or not (and some do not) the genetic engineer is beginning to rival nature in adapting biological systems for specific purposes in our production of organisms. □

*Jim Peacock is in the CSIRO Division of Plant Industry, GPO Box 1600, Canberra, ACT 2601, Australia.*

---

BIOMINERALIZATION

# Bacteria and the Midas touch

Stephen Mann

GOLD is the most precious of metals. How it comes to be concentrated in the stream beds of various regions around the world is a long-standing issue. The conventional view is that the placer deposits originate by mechanical weathering and transport of distant vein material. But John Watterson[1] now provides compelling evidence that many Alaskan gold nuggets arise from microbially induced chemical deposition. Although the involvement of bacteria in gold geochemistry is unlikely to set alight the City or initiate a biotechnological gold rush, it adds a little more glitter to the idea that microbiological processes are of fundamental importance in the cycling of metallic elements.

For some years now, bacterial activity has been implicated in the weathering, leaching and deposition of mineral ores. Microbes such as *Thiobacillus ferrooxidans* and *T. thiooxidans* are effective in leaching metals such as copper and uranium from insoluble minerals by redox processes at the mineral surface[2]. Alternatively, bacteria can accumulate metals from solution by biosorption at the cell surface. In many cases, the metals are deposited as insoluble oxides and sulphides, and large-scale and long-term activity can lead to important geological formations such as the Baltic Sea ferro-manganese concretions[3]. The possible influence of bacteria in gold geochemistry had been suggested[4,5] but without much supporting field evidence. This is now rectified by Watterson[1], who presents striking evidence of lacelike, gold-decorated microbial structures associated with placer gold particles from nine Alaskan sites (Fig. 1).

What is even more exciting, is that the gold facsimiles are of such high resolution that there is a good preliminary evidence for the presence of specific bacteria — the *Pedomicrobium*-like budding bacteria. These bacteria are known to be involved in iron and manganese oxide deposition processes[3], so it is a surprise to discover that they are also associated with gold accumulation. Scanning electron microscopy images suggest that the process of gold acquisition occurs during microbial growth and that this is sustained by the budding growth habit of *Pedomicrobium* which enables the colony to remain one step ahead of irrevocable entombment within its own gilded cage (Fig. 2). Although a mecha-