p-Tools

Productivity methodologies, tools, and techniques

Using green biotechnology to increase agricultural/crop productivity

Increasing productivity is key to staying competitive in farming. Very simply, this means to produce more with less or to produce better quality with the same inputs. Both give farmers or other producers more value for their efforts. The Food and Agriculture Organization of the UN has estimated that food production will have to increase by about 70% to keep pace with demand by 2050. Biotechnology is one set of tools which offers the potential to increase production significantly by increasing yields and reducing losses, while concurrently ameliorating the effects of climate change on food availability, physical access, and its utilization.

Agriculture is an important area for applying biotechnology. Modern biotechnology applications in agriculture may be divided into several broad categories such as:

1) Diagnostic and early detection tools;
2) Inputs such as biofertilizers and biopesticides;
3) Crop planting material derived from micropropagation and tissue culture;
4) Crop varieties derived from marker-aided selection; and
5) Crop varieties derived from genetic engineering.

Scope of green biotechnology to improve productivity

In its traditional sense, biotechnology was considered any technology based on biology, and would therefore include microbial fermentation. In its modern, contemporary sense, biotechnology is taken to mean new cell and tissue culture techniques as well as the new recombinant DNA technologies that utilize some aspect of genetic engineering to produce transgenic plants. At a practical application level, biotechnology includes any technique that uses living organisms or substances derived from those organisms to make or modify a product, improve plants or animals, or develop microorganisms for specific uses. Biotechnology therefore includes a wide set of tools making use of biological processes or organisms in their original or modified form to meet human needs.

Green biotechnology is biotechnology applied to plant agriculture. An example would be the selection and multiplication of plants via micropropagation or tissue culture. Another example is the designing of transgenic plants (genetically modified or engineered plants) to grow under difficult conditions such as drought or flooded environments. A further example is the engineering of a plant to express a protein that, when ingested by certain types of insect pests, will kill those insects and thereby reduce the need for the application of chemical pesticides, ultimately making them more environment friendly.

For small firms and farmers in Asia, productivity may be influenced by factors that: 1) affect the firm's relative cost of production, such as input costs (chemicals, labor, raw material, etc.), and profit/profitability; 2) increase the total output of production for the same level of inputs; and 3) affect the quality, or perceived quality, of a product or business enterprise. In practice, improved productivity in agriculture through individual farmers and firms may be obtained by reducing input amounts and costs, increasing yield, and improving product quality. Green biotechnologies allow farms to achieve one or more of these benefits.

Proven technologies for productivity improvement

Diagnostics

Diagnostic kits produced from biotechnology include those for confirming specific animal and plant diseases; many are based on immunology, e.g., the kit for detecting the fungus causing rice blast disease, *Magnaporthe grisea*, which acts to detect the presence of the fungus and also confirm its identity. This early detection and confirmation of a disease enables growers to take prophylactic action before any damage is caused. Another example relates to the global trade in food items such as soybeans and corn, most of which now contain specific genes and gene products that are regulated. With increasing trade in biotechnology products, the detection of the low-level presence of such products has spawned an industry to help countries meet international reporting requirements.

Biopesticides and biofertilizers

Biopesticides are either material derived from a biological origin or biological organisms themselves used to control pests (insects, pathogens, and weeds). A form of biopesticide is the microbial insecticide based on a bacterium called *Bacillus thuringiensis* (commonly known as Bt) which is fatal to a certain class of insects belonging to the butterfly family and includes many damaging pests such as the diamond-backed moth whose caterpillars feed on cabbage. Bt is produced en masse and sold to organic growers in particular to help them control this moth. Biofertilizers are commonly microbes such as *Rhizobium* species, which when applied to crops help them to absorb more nutrients or directly provide nutrients to the crops. The biopesticide and biofertilizer industry has grown in recent years due to two factors: the demand by the organic food sector for substitutes to replace synthetic chemical fertilizers and pesticides; and the demand for reduced dependency on petroleum-based fertilizers and pesticides. This has also been supported by scientific breakthroughs in isolating microbes and engineering them for increased efficiency as fertilizers and pesticides, as well as in technology to prolong the effectiveness of the microbes concerned.

Micropropagation and tissue culture

One of the challenges facing all growers is to produce plants with the same quality and growth at approximately the same rates and to the same sizes. Through micropropagation of selected genetic material and using

Figure 1. Uniform lettuce plants produced using seedlings derived from tissue culture.

tissue culture to multiply uniform planting material in large numbers (Figure 1), flower and vegetable growers in particular have been able to maintain high and competitive levels of production. Crop varieties derived from tissue culture are also grown widely, especially through the planting of clones derived from the same genetic background such as the large areas of rubber and oil palm in Southeast Asia.

Genetically improved crop varieties

Genetic improvement of plants to produce new varieties expressing preferred traits (such as improved pest and disease resistance, tolerance to environmental stress, etc.) have been made possible through biotechnology tools such as tissue culture, marker-aided selection, and genetic engineering. Tissue culture, apart from mass producing uniform plants, has also been used to create varied cell lines from which specific lines have been selected with useful properties. Marker-aided selection makes use of information from genetic markers, which indicates the presence of specific major genes in a crop parent used in plant breeding; this makes breeding less of a process based on phenotypes and more based on genotypes.

Biotechnology crops, also known as genetically engineered crop varieties or genetically modified (GM) plants are the most widespread and high-valued of all modern green biotechnology applications. For example, Table 1 shows how a GM crop engineered to resist insect pests of cotton, called Bt cotton, has positively affected productivity factors in India. Table 2 shows the productivity factors directly attributable to biotechnology and the range of advantage conferred by biotechnology crops.

Table 1. Summary of 12 Indian studies on the benefits of Bt cotton, 1998–2010.

Production factor	Positive change in metric range
Yield increase	31% to 60–90%
Reduction in number of insecticide applications	21–75%
Increased profit	50–110%
Average increase in profit per hectare	US$76 to US$250

Source: W.C. James. 2012. *ISAAA Brief No. 44.* International Service for the Acquisition of Agri-biotech Applications: Ithaca, NY, USA, Table 18.

Table 2. Advantages conferred by biotechnology crops.

Competitive or productivity factor	Biotech crop trait	Advantage
Input cost: pesticides	Bt (all crops)	Reduced cost to farmers
Input cost: labor for pest control	Bt (all crops)	Reduced cost to farmers
Product quality	Bt (corn)	Reduced molds and mycotoxins
Product quality	Delayed senescence	Extends shelf life and freshness of fruit and vegetables
Farmer health	Bt (all crops)	Reduced exposure to pesticides and reduced medical expenses
Environmental health	Bt herbicide tolerance (all crops)	Resurgent populations of beneficial organisms in agro-ecosystems
Net profit	All traits	Increased profit per hectare to farmers; cheaper products

The data show that the greater competitiveness of biotechnology crops is conferred directly through input cost reduction, improved product quality, and profitability. In addition, other positive outcomes such as improved farmer health and environmental quality contribute to competitiveness and sustainability. All competitiveness factors were increased by more than 10% each, attributable to biotechnology. Apart from the above, biotechnology crops confer stability of production every season to assure product buyers continued access to food or fiber products. Most APO member countries now have the capability and regulatory systems in place to develop and grow biotechnology crops.

Increasing productivity is an important objective in the face of reduced arable land, labor, and water in Asia, and therein lies the huge potential for green biotechnology to contribute to sustainable development. The adoption and use of diagnostics, biofertilizers/biopesticides, marker-aided selection, and tissue culture techniques are widespread across the Asia-Pacific region and in some countries have even generated multimillion dollar businesses. What offers the most potential to increase productivity and therefore competitiveness is the underexploited applications of genetic engineering in the Asia-Pacific.

Professor Paul Teng holds a PhD in agricultural microbiology/systems research from the University of Canterbury, New Zealand. He has held positions in academia, the private sector, and international organizations and has published eight books and over 200 technical papers on topics including plant pathology, biotechnology, food security, and agribusiness. He is currently a professor at the Nanyang Technological University, Singapore, holding appointments as Dean of Graduate Studies & Professional Learning in the National Institute of Education and Senior Fellow (Food Security) in the S. Rajaratnam School of International Studies.