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Development of Agricultural Biotechnology in Malaysia in Comparison to Global Status

MAHALETCHUMY ARUJANAN
Malaysian Biotechnology Information Centre (MABIC), 4-8-27 Monash University Sunway Campus, Jalan Lagoon Selatan, Bandar Sunway, 46150 Petaling Jaya, Selangor Darul Ehsan, Malaysia

Agricultural biotechnology is rapidly advancing and is providing a number of tools to improve crop production that not only is important to feed the global population but also in healing and fueling the world. The global scientific community is already advancing from conventional breeding techniques and genetic engineering to more precise technologies such as gene editing. While Malaysia has a strong commitment to develop biotechnology and bioeconomy, and had a good start with tissue culture, the country is lagging behind in modern biotechnology.

This paper outlines the global status of agricultural biotechnology, in particular developments in Asian countries. Malaysian biobased activities in the area of agriculture do not employ advanced modern biotechnology, making Malaysia to lag behind in agricultural biotechnology. The issues and challenges that need to be addressed for Malaysia to transform current research activities to the level that is comparable to global status are discussed.

Keywords*: Genetic engineering, gene editing, Malaysia*

AGRICULTURAL BIOTECHNOLOGY

Initiatives to build a robust biotechnology industry in Malaysia started as early as the 1980s. This was inspired by the rich biodiversity in Malaysia and the need to create a diverse stream of revenue and employment opportunities for the growing population. The government clearly understood the potential of biotechnology in feeding, healing and fueling the world. While biotechnology can be categorised into three main sectors, namely agricultural biotechnology, medical and healthcare biotechnology, and industrial biotechnology, it is becoming increasingly difficult to create distinct categories as there is huge overlap among these sectors. In many cases the upstream activities belong to one category and the downstream activities fringes another category. Production of industrial compounds from agricultural biomass, for example combines both agriculture and industrial biotechnology. Other examples are development of functional foods and healthcare supplements from medicinal plants, production of biofuel where feedstock is derived from agriculture, and plant made pharmaceuticals and industrial proteins that involve both agriculture and healthcare. Plant breeding and development of resilient and high yielding crops are the basis to other areas of biotechnology. Thus, agriculture is gaining attention once again and Malaysia cannot ignore the importance of it in developing the biobusiness sectors.

The areas in agricultural biotechnology

Contrary to popular belief, agricultural biotechnology is not all about the development of genetically modified (GM) crops. GM technology is just one of the tools in the toolbox of plant breeders. The biotechnology tools that are important for agricultural biotechnology include tissue culture and micropropagation, molecular breeding and marker assisted selection, genetic engineering and GM crops, and molecular diagnostic tools (ISAAA, 2014). The latest addition to this toolbox is gene editing such as Zink Finger Nucleases (ZFN), Transcription Activator-like Effector Nucleases (TALENs), Clustered Regularly Interspaced Short Palindromic Repeats (CRISPR), and Oligonucleotide Directed Mutagenesis (ODM).

THE GLOBAL STATUS

The most popular and widely adopted product of agricultural biotechnology is GM crops or also known as biotech crops. Since its introduction in 1996, biotech crop hectares increased by more than 100-fold from 1.7 million hectares in 1996 to 181.5 million hectares in 2014 (James, 2014). The number of countries planting biotech crops more than quadrupled from six in 1996 to 28 in 2014, with 18 million farmers growing the crops. The top biotech crops in order of hectarage are: soybean, maize, cotton, and canola, followed by alfalfa, sugar beet, papaya, squash, poplar, tomato, sweet pepper, and brinjal. These statistics show that biotech crops are the fastest adopted crop technology in the history of agriculture, reflecting its benefits to the farmers. The countries that grow biotech crops, the hectarage and crops approved for cultivation are shown in *Figure 1*.

There are dozens of biotech crops in the pipeline in many countries globally, a large number are in advance stages of development and many others are awaiting approval from the authorities. The biotech crops in research pipeline in developing countries in Asia are as in *Table 1*. Contrary to GM research in Malaysia which is still at its infancy stage and years away from commercialisation, crops shown in *Table 1* are at mature stage of research. Another important contrast is that many of these countries have strong research partnership with private sectors which promises higher possibility of approval and commercialisation. A key development in Asia that is worth mentioning is the development of drought tolerant sugarcane by Jember University, a public sector university in Indonesia and the crop was approved by the Indonesian government in 2013 (Waltz, 2014). This milestone achieved in Indonesia should set an example that GM technology could be developed and commercialised by public sector scientists.

The current direction for agricultural biotechnology has even shifted from GM to gene editing and RNAi technology which do not involve transfer of foreign genes and promises lesser regulatory scrutiny and public concerns. The first gene-edited crop to be approved is Canola tolerant to sulfonylurea or SU Canola™. It was developed by Cibus Global, a company based in San Diego using non-transgenic breeding through precision gene editing. It was approved by the US and Canadian regulators in 2014 and first grown commercially on 10 000 acres (4 000 ha) in the USA in 2015 (Arujanan, 2016).

Two products Innate™ potato and Arctic Apple, developed using RNAi technology to silence different proteins were also approved. Innate™ potato which was approved in the USA in 2014 has reduced acrylamide, starch and is resistant to late blight. Whereas, Arctic Apple is expected to be planted in 2016 and is a non-browning apple (Arujanan, 2016)

According to the United Nations, the world population reached 7.3 billion in 2015 and 60 per cent of the global population lives in Asia

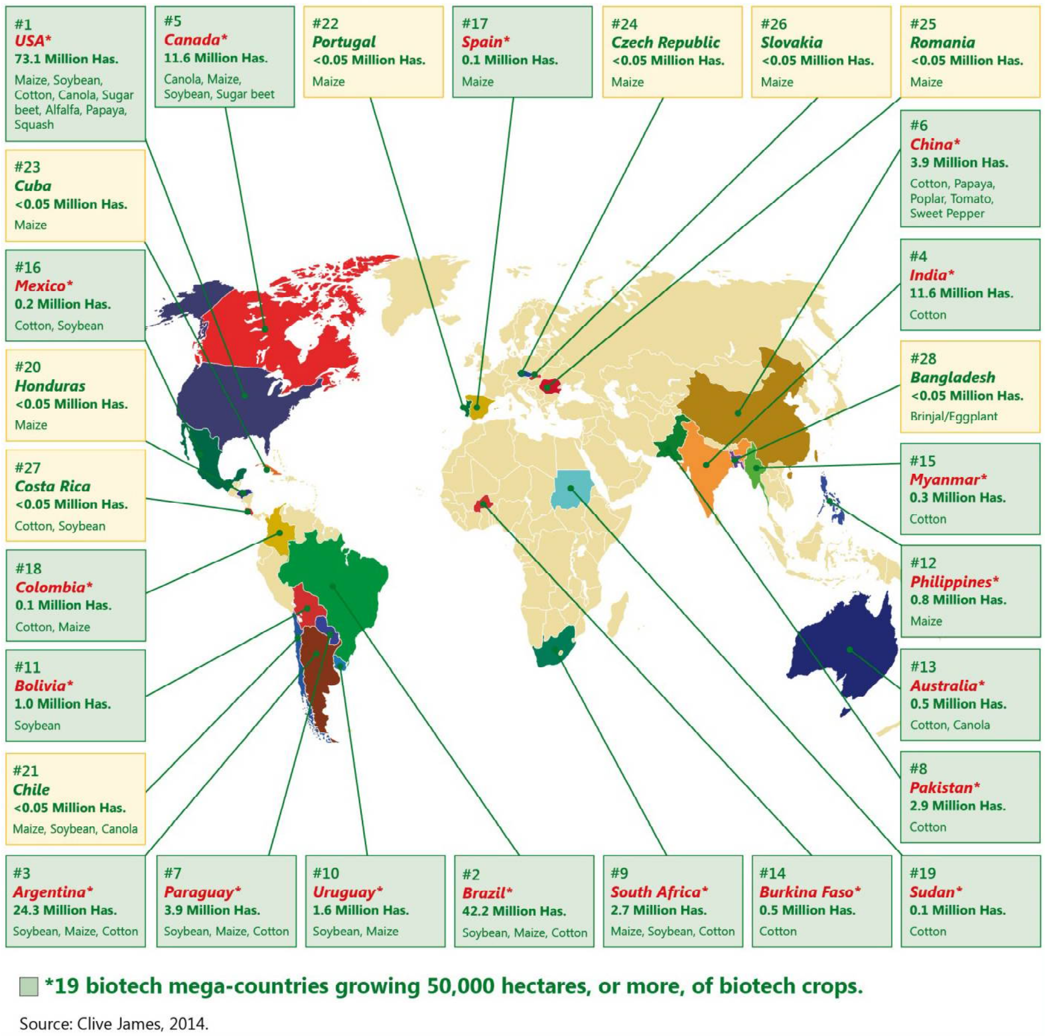

Figure 1 Global map of biotech crop countries and mega countries 2014

(4.4 billion). It is estimated that the population will reach 8.1 billion by 2030. The increase in population directly results in the increase of per capita food consumption. Urbanisation and increase in Gross Domestic Product (GDP) of a country also contributes to the shifting towards more consumption of dairy products and meat, thus, increased demand for grains for the livestock and poultry industry is expected. Another study published by Transparency Market Research (2015) reports that the global agricultural biotechnology market was worth US$15.3 billion in 2012, and is expected to double by 2019, growing at a 9.5 per cent compound annual growth rate (CAGR) from 2013 to 2019. The global status of agriculture biotechnology certainly dwarfs Malaysian initiative and enthusiasm in this area.

The question for Malaysia should be: What is our market share in this space and the rate

TABLE 1
BIOTECH CROPS IN RESEARCH PIPELINE IN ASIAN COUNTRIES

Country	*Traits*	*Crops*	*Developer*
China	High lysine and/or low phytate content, insect resistance, herbicide tolerance, disease resistance	Maize, rapeseed, rice, soybean and wheat	Various national research institutes and universities
India	Insect resistance, disease resistance, drought tolerance, delayed ripening, male sterile, female fertile, high iron, enhanced vitamin A	Cotton, eggplant, chick-pea, castor, sorghum, sugarcane, rice, tomato, groundnut, papaya, potato, watermelon, mustard	Various national crop research institutes, universities, public-private partnerships
Bangladesh	Insect resistance, disease resistance and enhanced vitamin A	Brinjal (eggplant), potato, rice	National crop research institutes with public and private partners
Pakistan	Virus resistant, insect resistant, herbicide tolerance, drought/ salt tolerance	Cotton, maize, sugarcane and wheat	National crop research institutes
Indonesia	Drought tolerance, disease resistance	Sugarcane, potato	National crop research institutes with public or private sector partners
Philippines	Insect resistance, enhanced vitamin A, delayed ripening	Eggplant, cotton, rice, papaya	National crop research institutes and universities with public or private sector partners

Source: FAO (2013)

of progress we are making to meet our food demand and national food security in the light of the rapid advancement of agriculture biotechnology?

MALAYSIAN TRADE AND BIOBUSINESS RELATED TO AGRICULTURE

Malaysia is a net food and feed importer, making us vulnerable in terms of food security. The country continues to be a net importer of food with annual imports of US$15 billion (USDA, 2013). Domestic production of corn is insignificant and grain corn is imported largely from Argentina (43% of total import), followed by Brazil and India to meet the demand of the livestock and poultry industry (USDA, 2012). Since 1998, the Government of Malaysia has been mulling over plans to produce corn locally, but no significant efforts have been made. Alternatives to corn as a protein source for the poultry industry was discussed in a task force formed by the Academy of Sciences in 2008 (Academy of Science, 2009). However, Malaysia's dependence on corn is only increasing every year.

The other area of concern is the country's seed industry. The success of a country in the area of agriculture can be measured by how vibrant its seed industry is. This is where Malaysia has serious weakness. While the global seed industry is valued at USD7.67 billion in 2009 with the Asia Pacific region as the biggest player, Malaysia is one of the smaller players in this sector. Malaysia's seed import is USD3.8 million and export is USD0.7 million. Malaysian farmers source their seeds from China, Thailand, Taiwan and Japan for vegetables, fruits, cover crops and ornamentals (Ugap *et. al*., 2013). The only seed research and production that is well developed is rice as the Malaysian Agricultural Research and Development Institute (MARDI) plays a pivotal role in this area. Currently, there is only one seed company in Malaysia, Green World Genetic (GWG) that produces corn and rock melon seeds.

With the realisation that the seed industry is critical to the agriculture sector, the development of the seed industry has been placed under the National Key Economic Areas (NKEA) as the fourteenth Entry Point Programme (EPP14) under the Tenth Malaysian Plan.

Malaysia also places great importance to bioeconomy and biobusiness and not just research and development in the areas of biotechnology. BioNexus is a special status awarded to qualified international and Malaysian biotechnology companies undertaking value-added biotechnology and/or life sciences activities. These companies enjoy tax privileges, funding support and capacity building programmes among other incentives. To date there are 262 companies with the Bionexus status of which 140 are involved in agriculture (www.biotechcorp.com.my).

The Malaysian Biotechnology Corporation (BiotechCorp), the lead agency for biotechnology and bioeconomy development in Malaysia realised that a standard GDP alone does not sufficiently measure bioeconomy progress and development. Thus, the Bioeconomy Comprehensive Index (BCI) was developed to monitor multiple aspects of bioeconomy on selected indicators that are reliable and reflective of the milestones that BiotechCorp is pursuing such as revenue, investment, innovation, research and development (R&D) spending and job income. The index grew by 5.4 per cent on average every year with strong performance recorded in 2007 and 2012 (www.biotechcorp.com.my). According to the Bioeconomy Transformation Programme Annual Report 2014, the total approved investment in the agribiotechnology sector among the Bionexus companies between 2005-2013 was RM2.3 billion with an R&D spending of RM46 million in the year 2013. Thus employment opportunity provided by this sector in 2013 was 1 485.

One robust area in agricultural biotechnology in Malaysia with a vibrant R&D and commercial activities is tissue culture. In Malaysia, the current production of clonal oil palm planting materials is 2.5 million ramets annually and is expected to grow to 5 million by 2010 from 11 commercial tissue culture laboratories and the Malaysian Palm Oil Board. This is still a remote number to supply 40 million ramets by 2017 (Kushairi, 2010).

Besides oil palm, tissue culture is actively pursued and commercialised for rubber, banana, pineapple, papaya, orchids, tongkat ali (*Eurycoma longifolia*), jatropha, vanilla, and a number of forest trees like gaharu and teak. However, the value of tissue culture industry in Malaysia could not be found in literatures. The other areas in the Malaysian agriculture sector are plant genomics, animal health, diagnostics and biologics, fertiliser and soil enhancer, animal breeding and reproduction technology, nutraceuticals. Overall, the

Malaysian agriculture biotechnology subsector was estimated to be worth US$ 67 million in 2009 (Frost & Sullivan, 2009). Nevertheless, Malaysia is still attempting low hanging fruits when compared to the global advancements in agribiotechnology, where countries are stepping into areas beyond genetic modification such as gene editing.

ISSUES AND OBSTACLES IN MALAYSIA

Research priorities

Research in the area of agricultural biotechnology started in Malaysia more than 30 years ago with tissue culture as the main activity. Currently a number of research institutions actively carry out research in agricultural biotechnology, namely the Malaysian Palm Oil Board (MPOB), Malaysian Rubber Board (MRB), Malaysian Cocoa Board (MCB), MARDI, Nuclear Agency and Agrobiotechnology Institute (ABI). Almost all public universities have research programmes in this area as well.

In the area of GM research, a number of crops have been attempted for various traits such as rice (enhanced yield, resistance to sheath blight and resistance to golden apple snail), papaya (delayed ripening and resistance to ring spot virus), orchid (increased flower shelf life and resistance to viruses), tomato (improved fruit colour), pineapple (resistance to fruit black heart), pomelo (improved fruit colour), passion fruit (resistance to viruses) (Pillai & Abu Bakar, 2007) and rubber (plant made pharmaceuticals). Unfortunately, most of these projects were abandoned halfway for a number of reasons.

Malaysia has unique challenges in adopting biotech crops as most of the biotech crops currently developed and commercialised globally are not suited for the Malaysian climate, landscape and availability of land. Corn could be the closest to be adopted but it requires post-harvest facilities for drying and storage and suitable terrain that could support high level of mechanisation. Grain corn cultivation in Malaysia is insignificant due to unfavourable economic feasibility (Salleh, 2009). Another challenge is the lack of private sector existence and participation in the country in GM research. In India, for example, there is active involvement of private sectors and a strong hybrid seed research and commercialisation that laid a foundation for GM seeds and research.

Malaysian crops, plant pests and diseases are not priority areas for multinational companies to embark on. Malaysia is also considered a small market that does not merit huge investments that is required for GM research. Thus, the public sector has to beef up to address food security and challenges faced by the farmers. Priority crops and the desired traits must be identified and made into national research programmes with long term vision and goals. In the pursuit of commercialisation among Malaysian fund providers and researchers, basic research is being neglected. The power of basic research must be realised. It takes more than 10 years to develop a biotech crop and plant made proteins and these are built upon strong basic research.

Funding

According to the National R&D survey by MASTIC (2015), there is a steady increase in R&D expenditure in Malaysia from 2000 - 2012 (*Figure 2*). While this is a healthy phenomenon, Singaporean initiatives dwarf the Malaysian R&D initiatives as part of the fund allocated is for capital expenditure. The

National Research Foundation (NRF) in Singapore announced a funding of S$19 billion (RM57 billion) for research activities for the next five years (New Straits Times, 2016). The funding will be allocated to projects that will make a difference to the lives of Singaporeans and also those that will rev up the economy. Public research institutes will get S$10 billion (S$30 billion) of this allocation.

Enabling and feasible regulatory framework

Malaysia has a balanced and science-based Biosafety Act that came into force in 2007. Regulatory and monitoring activities of GMOs are conducted by the Biosafety Department with advisory role played by Genetic Modification Advisory Committee (GMAC). The system must be commended for their diligence. However, Malaysian scientists are shying away from the procedures due to the amount of paperwork and reporting. The scientific fraternity must understand that regulatory tasks are part of GM research and scientists in all the countries that have successfully put biotech crops in the field go through the same procedures in their countries. In a workshop organised by the MABIC and ABI in 2015 (Stakeholder Workshop: Strategic

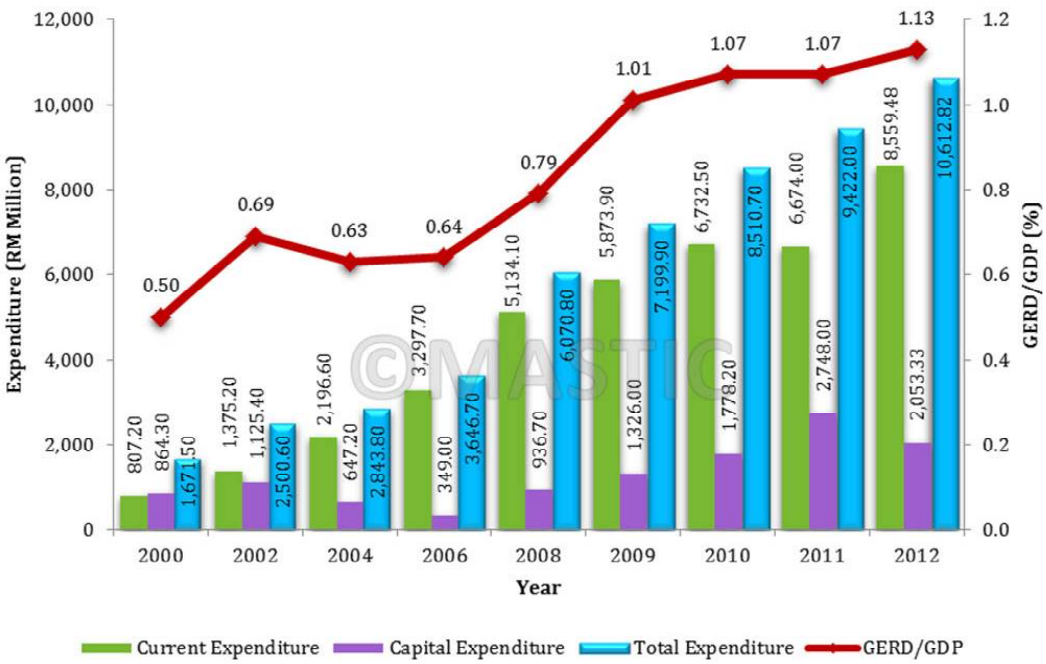

Figure 2 R&D Expenditure 2000 – 2012 (MASTIC, 2015)

The gross expenditure (GERD) in Malaysia has been steadily increasing since 2000 as shown in the Figure. For fiscal year 2012, Malaysia recorded the highest GERD recorded at RM10 612.8 million, an increase of 74.8 per cent over the GERD value in 2008 (RM6,070.8 million). The intensity of R&D, a measure of the percentage of GERD to GDP (GERD/GDP) also shows an increment since 2004. In 2012, the GERD/GDP was 1.13 per cent, an increase of 43 per cent compared to year 2008 (0.79%). (MASTIC, 2015)

Planning to Accelerate Agribiotechnology Development in Malaysia), scientists involved in GM research cited regulatory procedures as the main reason for them to switch to non-GM research.

Public engagement and understanding of biotechnology

There is a strong need to create understanding of biotechnology among all key stakeholders such as scientists, policymakers, politicians, regulators, farmers, media, religious scholars, and the general public. The science, regulations and policies, and ethics and religions must be understood by all parties to devise effective strategies and implementation programmes. Science communication often takes a back seat in the interest of research. As scientists are not the best communicators who could repackage research information and translate it into laymen language, science communicators should be engaged and hired by all universities and research institutes so that research news reaches the public domain.

CONCLUSION

Interest in agriculture must return in a big way with strong political will for Malaysia to be a leader in this area and more importantly to provide the food and feed needs of the nation. It is important to establish a national priority in this area, focusing on key crops that would bring socioeconomic benefits to Malaysia. Malaysia has to restore and strengthen its ability to invest in research and turn these investments into commercial products and services. Nevertheless, a rush into commercialisation will also lead to low hanging fruits with weak innovation and inability to compete at international market as well as get approvals from international regulators. Malaysian innovation has to be strongly backed by fundamental science.

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