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Challenges for Sustainable Agricultural Biotechnology Development in Indonesia

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ABSTRACT

The development of biotechnology in Indonesia is a response to more serious food security challenges as the growth of food yield in the last decade has been much less than that of population. This paper describes biotechnology development in Indonesia, examines government policies related to biotechnology, and exposes challenges facing biotechnology development in the future. It also suggests that the government should provide clearer policy actions including fiscal incentives and legal protection, involve the private sector in developing innovations in research and development, and encourage wider participation of civil society in the development of biotechnology.

INTRODUCTION

The world population increases yearly. At present, it is estimated that 900 million of the 5.8 billion world population are experiencing hunger. They mainly live in Asian and African countries where per capita agricultural production has been stagnant, if not declining. Pests and plant diseases, as well as bad weather, are among the factors influencing this negative tendency. The population growth rate, which in a number of countries exceeds the growth rate of food production and/or food availability, worsens the situation.

Possibly, the relatively slow growth rate of food production is because of stagnant food yield

and agricultural land conversion. For example, paddy production in Indonesia grew only by 1.01 percent per annum (pa) during 1996-2007. Within the same period, the yield growth rate was only 0.58 percent pa. Without effective government regulation, it is difficult to reduce the conversion of agricultural land. Failure to overcome land conversion will put food security at high risk, unless there are positive increases in the yield of food commodities.

“Excessive” industrialization has resulted in externalities that threaten the sustainability of agricultural, and perhaps also economic, systems. Such industrialization has induced deforestation and accelerated agricultural land conversion. Furthermore, it has instigated sharp

increases in emissions of carbon dioxide and greenhouse gasses in recent times. In turn, this has led to increases in the world temperature, including that in Indonesia. The combination of agricultural land conversion, adverse effects of deforestation, and increases in temperature, which affect land water availability as well as rain pattern, has in turn affected plantation areas (Siregar and Winoto 2007).

In Indonesia, the rise in temperature has caused below-average rainfall in certain areas and higher rainfall in others, leading to drought and floods. In 1995-2005 for instance, flooded paddy fields amounted to 1.93 million hectares (ha), of which 0.47 million ha were destroyed. During the same period, drought paddy fields amounted to 2.13 million ha, of which 0.33 million ha could not be harvested. In 2006, 189,800 ha of 577,000 ha of flooded and drought paddy fields could not be harvested (Anonymous 2007). With an average yield of 5 tons of dried husk paddy per ha, this is a loss of about 0.95 million tons.

Under these circumstances, efforts to improve yield are necessary. It seems likely that if such efforts were made only through conventional ways of enhancing agricultural technology, increases in food consumption will not be met sufficiently. The need to develop or adopt new technologies, which aim to boost not only food production but also food quality in an environment-friendly manner, continues to increase. Biotechnology responds to this need.

“Biotechnology” is often used to refer to genetic engineering technology of the 21st century; however, the term encompasses a wider range and history of procedures for modifying biological organisms according to the needs of humanity, going back to the initial modifications of native plants into improved food crops through artificial selection and hybridization. According to the United Nations Convention on Biological Diversity (UNCBD), biotechnology is any technological application

that uses biological systems, living organisms, or derivatives thereof to make or modify products or processes for specific use.

Through biotechnology, it is expected that new varieties of food plants that are resistant to pests and diseases as well as adaptive to climatic changes can be developed.

This paper begins by describing the progress of biotechnology and explaining the uncertainties of the public regarding the effects of transgenic plants on human health and the environment. It then discusses the policies related to and the challenges to the development of biotechnology in the future, followed by the concluding remarks.

BIOTECHNOLOGY DEVELOPMENT IN INDONESIA

Progress in the Last Decade

Among food commodities, paddy still plays a dominant role in Indonesia. Its participation rate in the food-consumption set reaches as much as 90 percent. In the world level, paddy is also among the most dominant food crops as it is the main source of staple food of majority of the world population, including inhabitants of China, India, Indonesia, Pakistan, Brazil, and Nigeria. Logically, improving paddy yield is the main priority of molecular-biology and transgenic-approach applications in Indonesia. The next priority is improving the yield and/or cost efficiency of other food crops.

A number of food crops resulting from transgenic development in Indonesia is presented in Table 1. These crops are being improved through further biotechnology development.

Genetic engineering for paddy (*Oryza sativa*) is not new in the biotechnology industry. Transgenic paddy enriched with iron, developed by Swiss scientists in the Federal Institute of Technology (ETH) Zurich, is already available. ETH cooperated with the University of

Table 1. Some transgenic food crops in Indonesia

Crop	Gene	Characteristic
Maize	Cry I ab	Stem borer resistant
Maize	EPSPS	Glyphosate herbicide tolerant
Maize	Pin II	Stem borer resistant
Soybean	Pin II	Fruit borer resistant
Soybean	EPSPS	Glyphosate herbicide tolerant
Paddy	Cry I ab	Stem borer resistant
Paddy	Cry I ab and GNA	Stem borer and brown plant-hopper resistant
Maize	Pin II	Stem borer resistant
Maize	Cry I ab	Stem borer resistant
Paddy	Bt and GNA	Stem borer resistant as well as stem borer and brown plant-hopper resistant

Notes: Transgenic plants possess a gene or genes that have been transferred from a different species. Though the DNA of another species can be integrated in a plant genome by natural processes, the term *transgenic plants* refers to plants created in a laboratory using recombinant DNA technology. The aim is to design plants with specific characteristics by artificial insertion of genes from other species or sometimes entirely different kingdoms.

Source: Kompas 2000

Freiburg in Bresigau, Germany in developing paddy containing phytic acid substance, which prevents iron loss in the human body. They modified a paddy gene with two types of new genes originated from mungbean and another microorganism. The amount of iron present in the resulting crop is twice as much as the iron content of the original paddy. The phytic acid contained in the paddy, which absorbs the iron, is eliminated through cooking.

Applying biotechnology to paddy has become more familiar since the launching of Golden Rice in 2001, which was hoped to aid millions of people threatened by death and blindness caused by vitamin A and iron deficiencies. The challenge then was not only to increase the yield to sufficiently overcome land conversion but also to improve the nutrient content of and add value to the rice. The research began with enhancing the pro-vitamin A content through beta carotene. Genetic engineering was employed because paddy is naturally unable to synthesize carotenoid.

The transgenic approach can be utilized due to advances in transformation technology with agrobacterium. In addition, the availability of molecular information of biosynthetic carotenoid in the bacteria and the plant provides more DNA choices. The production of the Golden Rice prototype uses japonica rice variety (Taipei 309), and the transformation technique utilizes agrobacterium and a number of beta carotene-producing genes from daffodil bacteria. Monsanto states that their paddy production is patent-free; anyone can access its genome database freely (Maharijaya 2008).

In Indonesia where rice is the staple food of most of the population, rice containing pro-vitamin A is very important (Suwanto 2000). Indonesian scientists, primarily in the Research Center of Biotechnology, Indonesia Institute of Sciences (LIPI), are currently developing transgenic paddy. It is now being field tested—for bio- and environmental safety, multi-seasons and multi-locations, among others—under the surveillance of the Ministry of Agriculture.

When it has passed the testing, the Academy expects to cooperate with the private sector to further develop and market the product.

LIPI has also produced a paddy cultivar, which is resistant to dry conditions and can be planted in areas with minimal water. This transgenic paddy is achieved by over-expressing a gene with transcript factor OsHOX, which is resistant to dry stress and has been tried in the plant model of *Arabidopsis thaliana*. LIPI has also produced transgenic paddy varieties, which are resistant to stem borer insects up to the fourth generation. These varieties are more resistant to stem borer insects than the existing varieties of *Rojolele*, *Ciherang*, and *Cilosari*. Test results suggest that the transgenic paddy does not affect the ecosystem in the sense that there is no gene distributed into other crops and the surrounding microbes and other insects are not influenced.

Furthermore, LIPI has produced transgenic paddy resistant to blast fungi. This is done by increasing the salicylic acid content in paddy by engineering the gene related to salicylic acid biosynthesis. The experimentation has been carried out until the fourth generation, and it suggests that a number of transgenic paddy genotypes are resistant to blast attack at different stages of growth (Anonymous 2008).

Novartis, formerly Ciba-Geigy, has successfully constructed transgenic maize (Bt maize) resistant to borer insects. In the United States, farmers have been planting this transgenic plant since 1996. Bt maize contains the Cry gene from *Bacillus thuringiensis*, allowing it to produce protein that can kill insects from the Lepidoptera group. This transgenic maize is expected to reduce the use of chemical pesticides; technically and

economically providing farmers with more profit; and is more environment friendly.

Another product, which has been field experimented in Indonesia, is a herbicide-tolerant maize called Roundup Ready (RR)-Corn¹ produced by PT Monagro Kimia, an affiliate of Monsanto. The experiment, which was carried out by the University of Lampung in 2000-2001, found that RR-Corn was more vigorous than other seeds. In terms of farming cost, the conservation tillage system was found to be the most efficient when RR-Corn was used (Sembodo et al. 2002). According to these researchers, revenue-to-cost ratio of RR-Corn with conservation tillage was from 1.83 to 2.61, significantly higher than that of other seeds (1.14).

In addition to paddy and maize, the genetic-engineering approach was also used in soybean. This plant has been modified genetically to tolerate glyphosate. In Indonesia, research to produce aluminum-tolerant soybean varieties is in progress. Biotechnology is not the same as the transgenic approach. LIPI has produced "soybean plus," which is soybean containing *Rhizobium* bacteria found in soil that can conduct nitrogen-adding processes. Eighty percent of the air contains nitrogen but plants, including soybean, are unable to use it directly. Properly mixing *Rhizobium* with soybean seeds will cause infection of the bacteria in the roots of the growing seeds, which would facilitate roots' nitrogen absorption and minimize the use of nitrogen fertilizer (urea) by up to 60 percent. As a result, the yield can potentially be increased from 1.2 t/ha (national average) to 2.6 t/ha, or even up to 3.6 t/ha in Musi Rawas regency.

In addition to paddy, maize, and soybean, transgenic cotton suitable for Indonesia's agro-

¹ Mention of proprietary names does not imply endorsement nor objection of the products by the authors

climate condition was also developed.² In 2002, the government permitted field testing of Bt cotton (DP 5690B) in the province of South Sulawesi through the Decision Letter of the Minister of Agriculture No. 107/KPts/KB/430/2/2001. According to a study undertaken by Kolopaking et al. (2003), Bt cotton yield (about 1204 kg/ha) was higher than that of non-Bt cotton by 57 percent in five districts of the province. There was also evidence that Bt cotton had lower production costs. As such, the net profit per ha of Bt cotton was 83 percent higher than that of its counterpart.

To summarize, biotechnology is potentially able to minimize the use and costs of agricultural inputs, improve yield, and conserve the environment. Hence, if properly managed, it increases the possibility of reducing poverty incidence and attaining sustainable farming practices. Despite this potential, many national observers claim that its progress is relatively slow. The slow advancement of biotechnology in Indonesia is perhaps due to apprehensions on the likely effects of transgenic plants or to relatively unclear policies of the government.

Qualms on Transgenic Plants

Plants naturally evolve. Their evolution happens gradually through the interaction between long-term environmental changes and gene variabilities. Human intervention through genetic engineering alters gene structures forcefully and rapidly. Many are concerned that the plants produced by these drastic alterations will jeopardize human health and the environment, and ultimately lead to societal losses.

No technological change is risk-free, and this applies to genetically engineered products. However, in many cases, damages because of transgenic products are exaggerated. Some of the possible risks of transgenic food are as follows:

- 1) Allergies, especially to consumers who are highly sensitive to food. Transgenic soybean with high methionin content posed this risk so that when subsequent tests proved that the plant caused allergic reactions in humans, its commercialization was stopped. Scientists found that the corresponding Bt gene was unstable and became inactive at pH under 5 and when the temperature reached 65 °C. This means that the gene would not have caused allergies to humans had the product been cooked properly.
- 2) Toxins, particularly of transgenic plants containing Bt endotoxin. The major concern is based on the toxic characteristic of the Bt gene, i.e., killing insects that eat the plant. However, this view is incorrect because the Bt gene is toxic only if it meets the receptor signal in the intestine of insects whose group of virulence is suitable. The Cry I gene works only for Lepidopterans, whereas the Cry III gene is effective only for Coleopterans. The intestine of insects possesses base pH, whereas the human intestine has acid pH and does not have the Bt receptor signal. The Bt gene is unstable and inactive when the pH is lower than 5. In addition, the Bt-toxin has been utilized by farmers in developed countries as a natural pesticide, which is safe for animals, useful insects, and humans. Thus, transgenic plants containing the Cry genes are non-toxic to humans.

² This is Bt cotton, a result of genetic engineering, in which a gene from the soil bacterium *Bacillus thuringiensis* (Bt) is transferred to the cotton genome. The presence of the Bt gene makes the plant resistant to a number of pests, including *Helicoverpa gelatopoeon*, *Pectinophora gossypiella*, and *Alabama argillacea* (Qaim, Cap, and de Janvry 2003).

- 3) Possibilities that the use of antibiotic marks in a transgenic plant may cause the bacteria in the human body to become resistant to antibiotics. Scientists claim that the possibility of the gene being transferred horizontally from the consumed transgenic product into the bacteria is very small. The gene is incorporated into the plant's genome through genetic engineering so the plant itself does not have any mechanism to transfer the incorporated gene into the bacteria in the human body.

As long as transgenic plant development is carried out accordingly and ethical principles are considered, it will not harm consumers. To date, there is no scientific finding in Indonesia reporting that the consumption of transgenic products causes health disturbances. Therefore, if continuously and carefully developed, transgenic plants may be seen as an important factor in future food and agriculture development.

BIOTECHNOLOGY: POLICIES AND CHALLENGES TO ITS DEVELOPMENT

Government Policies

Controversies continue to surround biotechnology products, yet there is no scientific proof that they are unsafe for consumption. In Indonesia, crop development through biotechnology approaches has been undertaken, including for paddy, maize, soybean, groundnut, sweet potato, sugarcane, cocoa, cotton, and tobacco. The use of transgenic plants are regulated by the government, as suggested by the Joint Decision Letter of the Ministries of Agriculture, Forestry, Health, as well as Food and Horticulture Numbers: 998.1/Kpts/OT.210/99; 790.a/Kpts.IX/99; 1145A/MENKES/SKB/IX/99; 015 A/N Meneg. PHDR/09/99. The government complements

this with a Guideline for Undertaking the Safety Testing on Genetically Engineered Food and Agricultural Products. The Joint Decision Letter has even been legally strengthened by the Government Regulation, PP No. 21/2005 on Biological Safety and Genetically Modified Products, and the formation of the Commission for Biological and Food Safety (KKHP) and a technical team to implement the regulation.

To date, the government still lacks clear policy actions despite this regulation. For example, it has not issued the needed regulation on maximum threshold of transgenic materials that is assumed to be safe. Thus, the Ministry of Research and Technology, which is external to the aforementioned signing ministries, suggests a set of policy arrays that can be summarized as follows:

- 1) *Developing coherent and consistent policies.* The policies to support biotechnology development must be comprehensive, (i.e., coherent and consistent across ministries) to minimize risks on human health, the environment as well as the economy, and to maximize gains from such development. At the international level, consistency and coherence will help develop the country's bargaining position in terms of trade negotiations; as well as to fulfill ratified agreements like UNCBD and others from the World Trade Organization, including Trade Related Intellectual Property Rights (TRIPs).
- 2) *Determining clearly the priorities and targets needed.* Targets of biotechnology development, which is financed by public investments, need to be identified clearly for each of the public research institutes responsible for such development. Priorities have to be set, starting from determining fields in which biotechnology development is urgently needed until assessing risks, management of risks, and plans of actions.

It is crucial at this point to involve the participation of various stakeholders.

- 3) *Assuring safe utilization of biotechnology.* A transparent and efficient legal system assuring that biotechnology products are safe and fulfill international standards is required. This is crucial in gaining the public's confidence in the products. The main functions of the legal system are, among others, to: (a) ensure that all biotechnology-processed products from domestic and foreign countries are subject to proper risk assessments, (b) assure that only products that have passed the required assessments and accord well with the international safety standards will be consumed or marketed, and (c) provide accurate information to the public regarding the risks and benefits arising from modern biotechnology development.
- 4) *Managing intellectual property rights.* A proper legal system consistent with international conventions is needed to protect biotechnology-based inventions and innovations. This is an important incentive not only for foreign inventors but also for local experts who have the opportunity to process the diverse domestic biological resources via biotechnology.
- 5) *Attracting the private sector to invest.* Private domestic and foreign investments should be attractive to biotechnology industries by providing a more competitive tax system and other fiscal incentives.
- 6) *Increasing support for public research and development (R&D).* Increases in financial support for R&D activities in the fields of agriculture, health, and industry are crucial both in local and national levels. Additional support is required for biotechnology products developed mainly for fulfilling the needs of the poor or peasant farmers.

- 7) *Supporting public education and awareness.* Science and technology education should be improved at all levels. This is to respond to needs in skill and awareness on biotechnology development and applications.
- 8) *Forming and maintaining infrastructure.* Infrastructure is one of the necessary conditions for attracting investments in biotechnology-based industries. The needed infrastructure include roads, telecommunication systems, electricity, water, and ports.
- 9) *Monitoring the progress of foreign biotechnology development and supporting the required international collaboration.* Regular and continuing analyses on the progress are needed to enable the government to correctly devote limited resources to developing state-of-the-art biotechnologies required to solve specific problems.

Challenges of Biotechnology Development in Indonesia

Many observers note that the progress of biotechnology development and applications in Indonesia is relatively slow. Biotechnology adoptions are still subject to pros and cons, and negatively viewed by some parties. The latter is probably because biotechnology products are perceived as the domination of multinational corporations of Western countries, whereby a particular party has been campaigning that biotechnology products are dangerous and should be rejected. This is possible because the media and other information conveyors in Indonesia in general do not have sufficient knowledge on the subject. Therefore, disseminating valid information on biotechnology to the public, including the media, thus increasing their familiarity with the subject, is still a challenge.

Another challenge is improving the existing legal backup. The only legal backup so far is Government Regulation No. 21/2005 on Biological Safety and Genetically Modified Products. The scope of this regulation has to be broadened and deepened as the subject has progressed dynamically.

The low public budget for biotechnology R&D is another challenge that must be overcome as soon as possible. To some extent, this may reflect a general perception that R&D is not a priority at this point. The budget deficiency in returns constrained the country's ability to improve quantitatively and qualitatively the human resource working directly on biotechnology development. Allowing this to persist will make the country critically dependent on imported biotechnologies and the resulting products. If the public budget constraint will continue, the country will have to cooperate with foreign governments to overcome financial problems in R&D, and with domestic and foreign private sectors to develop biotechnology products, especially food crops.

Improving coordination and cooperation across domestic R&D institutions is another challenge. Without sufficient coordination or cooperation there would be a waste of finances in the form of unnecessary overlaps in research and other related activities. Simplifying the bureaucratic process in obtaining intellectual property rights and providing sufficient legal protection for the obtained rights are also challenges that must be surmounted.

CONCLUSION

Indonesia has abundant natural resources and rich biodiversity. However, its poverty rate is still above 15 percent and food security is threatened by high fluctuation in commodity prices, agricultural land conversion, relatively stagnant yields of food crops, and climate change. Feeding the population of about 230

million growing at the rate of 1.3 percent per annum is not an easy task, especially in this era of regional autonomy. Regional governments have full independence to plan and conduct their regional development, including that of agriculture and food. Under these circumstances, maintaining food security is very important.

Biotechnology development, especially in food, is one of the solutions. Though still in its infancy in Indonesia, biotechnology needs significant R&D efforts to be at par with other countries that are advanced in the field. Such efforts must be taken to improve the food crop yields and to optimize biodiversity. Since results of these efforts are generally apparent in the medium- to long-terms, this is not attractive enough for domestic investors who prefer mostly short-period alternatives. The government, through its research institutes and universities, must therefore play its role in this direction. Sufficient budget is crucially needed to accelerate R&D efforts.

Private-sector collaborations would normally be more plausible in developing further the obtained inventions or in scaling up the resulting innovations. Perhaps, private-sector involvement at this stage is no less important than the government's role in the previous stage. Without the private sector, it would be very difficult to disseminate the products to farmers or consumers. Proper fiscal incentives, as well as legal protection on investments, are vital to increase private-sector involvement.

Controversy in the development and use of transgenic products at any time must be handled wisely by the government. It is important for the latter to conduct necessary testing or evaluation of the products regularly and disseminate the results to the stakeholders accordingly. Clearer policies in protecting the consumers and the environment, supporting biotechnology R&D, and attracting the private sector and participation of civil society are certainly required.

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