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Needs, opportunities and challenges for crop improvement in Indonesia

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Abstract. Indonesia is one of the countries with mega diversity. However, challenges in varietal improvement might affect the national agricultural development in Indonesia. This article discusses the need for improved crops, opportunities, challenges for crop improvement and addresses strategic crops improvement by applying advanced biotechnology in Indonesia. A growing population demands increased food supply. Thus, food self-sufficiency is a strategic agricultural development program due to its broad impact. The supply of fibre, feed, and fuel is also necessary for industrial development. At present, changes in land quality and climate influence agricultural productivity, especially crop productivity and quality. Therefore, crop genetic improvement significantly contributes to increase their production. The emerging biotechnological approaches, particularly new breeding techniques involving diverse genetic resources from Indonesia, would rapidly expand the gene pool for plant improvement. Moreover, accessible information technologies along with exchanges of genetic resources through the multilateral system, offer a new direction and partnership for advanced research. However, inadequate human resources, infrastructure, low investment in long-term research and lack of collaboration and coordination among research organizations can hinder the crop improvement. Additionally, genetic erosion and genetic resources management remain a concern. As strategies to engineer crop improvement, many approaches have been centered on prioritized national strategic crops for desired traits to overcome national issues. Possible breeding techniques can be enriched by exploring new supporting technologies including molecular markers, genetic engineering and genome editing, as well as by co-development and transfer of technologies for overall development in Indonesia.

Keywords: breeding techniques, crop improvement, plant genetic resources.

1. Introduction

Since the first half of the century, global demand for food, feed, fibre and fuel predictably grow. On the other hand, crops might also be used for other industrial purposes. An increased agriculture demand will thus put a high pressure on genetic resources (GR), which become increasingly scarce. Agriculture is required for adapting and mitigating climate change and maintaining biodiversity. For such purposes, optimal utilization of GR along with new technologies are needed to produce improved crops. In developing countries, approximately 80% of agricultural production increases are from raised yields and cropping system [1].

Indonesia is known as one of three developing countries in Southeast Asia with mega diversity. Nature conservation and sustainable use of biodiversity do not stop at the national borders [2]. Goals of the development of food and agriculture would be to achieve the status of a world's food supplier in 2045. To achieve the goals, an efficient, independent, advanced, highly competitive and sustainable food and agriculture industry should be created through high effort on management and utilization of GR.

High diversity of plant genetic resources (PGR) in Indonesia could be a foundation for the development of new varieties for present and future challenges, such as various biotic and abiotic stresses and other critical agricultural traits via breeding program [3]. Moreover, PGR for agriculture is the vital cornerstone of global food security. The rich collection in Indonesia comprises diverse genetic materials including traditional varieties, modern cultivars, introduced accessions, and their wild relatives. Importantly, the agricultural diversity is needed to efficiently maintains levels of food production and to confront future challenges [4], which involve a biotechnological approach [5]. However, challenges in varietal improvement might affect to the national agricultural development in Indonesia. For this reason, Indonesia increasingly incorporates sustainable use of GR through advanced biotechnology and omics opportunity.

A mandate to perform crop improvement program in Indonesia is given to governmental research centres/institutes, which are supported by academic resources from universities. All these organizations complement the Indonesian Agency for Agricultural Research and Development (IAARD), being a central institution to conduct and produce new varieties tasked by Ministry of Agriculture. Public sectors also play an essential role, in line with the governmental program to fulfil consumer demands.

To date, Indonesia has not taken full advantage of this important potency of high GR diversity for crop improvement. Therefore, this review summarized the critical need for improved crops, opportunities and challenges for crop improvement, and strategic crops improvement by applying biotechnology in Indonesia.

2. The important need for improved crops

Agricultural biotechnology is expected to contribute to food security not only in the world, but also in Indonesia. Indonesian Statistics Agency has estimated that Indonesia's population will surpass 310 million people by 2045. This projection means that over the next 30 years, more food stuffs must be produced to ensure that food supplies are sufficient in a sustainable manner. For this reason, food self-sufficiency was declared by the Indonesian government. It would be followed up by the World Food Supplier Grand Design in the form of a roadmap for seven strategic commodities, which comprises six plants species and one livestock in 2016–2045. Rice self-sufficiency was planned to be achieved in 2016, while the target of achieving corn self-sufficiency started in 2017. Self-sufficiency of soybeans, sugar consumption and industrial sugar would be achieved in 2019, 2020 and 2025, respectively. To achieve these, crop yield has to be increased and the supporting role of all possible biotechnology techniques and PGR for crop improvement need to be exploited. Agricultural productivity must be improved through high effort in both favourable and marginal areas.

Nowadays, people increasingly consume livestock products, which automatically require more grain. Furthermore, the rising population is being accompanied by a growth of household pet worldwide. A trend in increasing amount of cereals and other grains being used as pet food is globally underway in several countries, including Indonesia [1]. Consequently, more extensive planting of higher yielding cereals and/or legume crops along with other functional feed will play an essential part in this effort.

The demand for fibre, from around 50 million tonnes/year today to 130 million tonnes/year by 2050, has been predicted. The prospects of flax fibre and other natural fibres, as well as their possible improvement, will need the aid of advanced biotechnology. Aside from fibre, renewable energy is an essential element for humankind to replace fossil fuels, which is already scarce. Renewable resources could complement non-renewable resources to meet demand, even though it may never be a competitive replacement strategy. Efficient biotechnology could be utilized to improve biomass fuels plants/crops as a result of their improved yield [1].

In the future, urbanization will continue and implicate an increased land degradation and conversion from the agricultural sector to industry and/or housing development in Indonesia [6]. Consequently, agriculture is forced to compete for land and water with urban settlements and industrial needs, but at the same time, it also has to serve on adaptation and mitigation of climate change. Climate change represents a major risk for long-term food security in Indonesia. Enough land, water and GR along with ecosystem service will be required for sustainable agricultural production [2,7,8]. To respond to these demands, progressive biotechnologies and breeding scheme are essential to contribute to crop improvement in Indonesia.

3. Opportunities and challenges for crop improvement

Mega diversity of Indonesia is well known for its unique insular nature. Diverse PGR has high values to facilitate their utilization for crop improvement. Crop genotypes, which are sourced from germplasm accessions, local/landraces, breeding lines, and wild species, have precious genetic variations for breeding program [9]. Thorough identification of genetic materials of important crops that exhibit potentially exploitable characteristics across Indonesia should be the first step of the breeding program.

Being an archipelago, Indonesia demonstrates an excellent example of GR spreads that are correlated with the eco-geographic origin. Under the management and inventory of the IAARD, several gene banks collected and conserved crops species. At least 10,893 accessions of food crops such as rice, soybean and other legumes, maize, root tubers, etc. are conserved in a national gene bank under the Indonesian Center for Agricultural Biotechnology and Genetic Resources Research and Development management. In particular, more than 1,171 rice accessions are collected at the Indonesian Center of Rice Research. Around 8,161 accessions of cereals, soybean, and tubers are conserved in a gene bank under the management of the Indonesian Center for Food Crops Research and Development. As many as 3,059 accessions of horticultural crops and 5,284 accessions of estate crops are collected in the gene banks of Indonesian Center for Horticultural Research and Development and Indonesian Center for Estate Crops Research and Development, respectively. In addition to *ex situ* collection, those research centers also perform *in situ* conservations for certain crops.

PGR management, including exploration/collection, conservation, characterization and evaluation, documentation and transfer of materials, and information databases are the main activities which have long been carried out in many institutions. Both *ex situ* and *in situ* conservations are essential for sustainable agriculture, today and in the future. Optimal utilization of PGR could be performed through characterization and evaluation of GR, genetic improvement/breeding and broadening of genetic diversity as well as wild relatives use. Thousands of accession of food crops, such as rice, maize and soybean under the collection of IAARD gene bank have been characterized and evaluated [10]. The potentials of various PGR in Indonesia are essential to be utilized for crop genetic improvement with the benefit of biotechnology approaches, such as molecular markers and genetic engineering. Omics will be a great opportunity, especially data that are based on genomics, proteomics and metabolomics that are linked with a comprehensive pathway of involved genes. Core omics technologies, along with relevant methodologies and their applications need to be addressed for crop improvement strategies [11,12].

The diversity of GR in Indonesia, however, is currently under threat. Deforestation, industrialization, and urbanization of humankind result in reduced land availability for PGR plantation and habitat loss. Long-term destruction of carbon storage ecosystem in the main islands like Sumatra and Borneo produced trans-boundary haze pollution from forest and peat fires, which also had an impact on the loss of GR [13]. Additionally, genetic erosion continues as a result of natural and humankind disturbances. Several factors cause it to rapidly increase, such as habitat damage due to industrial and residence utilization, disaster and environment degradation, pest and diseases and agricultural change system including low attention to cultivation and slow regeneration ability [14]. Continuous hybridization, therefore, should be designed in parallel with a long-term program to maintain their GR. Therefore, PGR consisting of cultivated and wild species along with their socio economics data have to be conserved, preserved and used wisely for breeding.

Information technologies and exchanges of GR and its associated information have rapidly developed for more than 15 years. Access on information and technology transfer have increased and become more important, which coincides with PGR utilization. Indonesia, being one of the contracting parties of ITPGRFA, through IAARD has contributed to increasing PGR exchange not only in national but also international levels, according to ITPGRFA multilateral system and national legislations. However, there is still no national law about GR, other than the ratification of the ITPGRFA and the Nagoya Protocol. The lack of national law governing GR results in the difficulties in implementing the Nagoya Protocol on Access and Benefit-Sharing (ABS), especially for negotiating the agreement on ABS for all available GR [10,15].

Indonesia has actively participated in partnership programs on agricultural research and development. In order to enhance crop improvement, the institutions/organizations have to support the aspects of capacity building, resources and active donor exploration to improve budgeting. Collaboration among various government agencies, universities and relevant stakeholders is crucial to agricultural innovation systems, such as climate change mitigation and PGR utilization. Low investment in research, particularly for long-term research on biotechnology, human resources and infrastructure is still a significant problem in biotechnological research in Indonesia. To achieve optimal utilization of PGR, which involves regional and international collaboration, several aspects such as strengthening capacity in all levels through the institution, human resources cooperation and capacity building, mechanism, finance and infrastructure; tightly linking between science and technology innovation and their application on PGR should be prioritized.

PGR plays an important role in capacity building and infrastructures over the past several years. Similar to other tropical countries that have rich genetic diversity, application of holistic biotechnology must be applied along with sound environmental policies in Indonesia. However, unlike Malaysia and Thailand, which have broader priority areas, Indonesia has focused on agro-industry and energy [5]. To achieve these priorities, emerging technologies in the field of gene and genomics, genetic engineering, genome editing and other omics could be a great opportunity as well as challenges to be applied by Indonesia scientists.

4. Strategic crops improvement

Strategic implementation of PGR diversity is preferably matched with crop improvement. Several approaches that are available could be useful for genetic improvement, including classical methods (introgression, incorporation and wide crosses); use of landraces/local accessions in breeding for specific adaptation to stressful environments; molecular markers and genomic research (diversity assessment, mapping of quantitative trait loci (QTL) and marker-assisted selection (MAS), advanced backcross QTL analysis and introgression, association analyses; gene transfer [16]; genome editing [11,17].

The Indonesian government plans to increase the productions of six national strategic plant commodities, namely rice, maize, soybean, chili pepper, shallot and sugar cane, in addition to cattle. Self-sufficiency and sustainable supply of those commodities are the main goals to reduce their import. For this goal, the government designed a master plan for each commodity. A road map for their production and distribution has been developed to direct the supporting policy to be applied. To encourage self-sufficiency in strategic commodities, a long-term policy is needed, although short and medium-term policies are also relevant. However, these policies are only applied to support or continue the steps in achieving the main objectives set out in the master plan.

Yield has to be increased and all possible biotechnology techniques must be exploited to support national strategic crops improvement. The IAARD, a leading governmental agency for research and development, have applied breeding and advanced biotechnologies to increase the productivity of the strategic crops along with its tolerance/resistance to abiotic/biotic stress, both for favourable and marginal areas. Genetic engineering has been applied to introduce gene constructs that govern traits related to resistance/tolerance to biotic stress (stem borer, brown planthopper) and abiotic stress (drought, salinity), and early maturity as well productivity in rice [10]. Several biotechnology-based improved varieties or products have also been generated. In rice, targeted gene mutation of *GA2Oox-2* using CRISPR/Cas9 allowed the production of T_1 mutant lines. Improved rice varieties resistant to blast and bacterial leaf blight (BLB) developed using marker-assisted selection have been released. A promising aromatic rice line and other lines resistant to various diseases (blast, BLB and brown planthopper) have been in the list waiting to be released to the public. Soybean varieties with high productivity generated by mutation breeding have been released and are expected to be grown in various areas. Maize, chili pepper, and shallot resistant to diseases are in development (Table 1). In addition to the national program, Indonesia actively implement co-development and transfer of technologies, which was established by ITPGRFA. Gene pool of local rice varieties from several ASEAN countries has been developed along with their phenotypic, molecular and genomic information. Adaptation assay of improved rice varieties from Indonesia, Philippine, Lao PDR and Malaysia could be one of the ways to support varietal improvement in Indonesia.

Table 1. Biotechnology-based crop improvement in IAARD.

Improved target traits	Approaches	Strategic crops	Sources
Early maturity	Genetic engineering (*CONSTANS*)	Rice	[10]
Nodulation stimulation	Genetic engineering (*GmNFR*)	Rice	[10]
Drought tolerance	Genetic engineering (*OsDREB1*, *OsERA*, *csp*, *OsCCPK*, *HVA1*, *SNAC1*)	Rice	[10]
Salinity tolerance	Genetic engineering (*OsDREB1*, *HVA1*)	Rice	[10]
Stem borer resistance	Genetic engineering (*Cry1A*, *Cry1Ac*)	Rice	[10]
Brown planthopper	Genetic engineering (*Tca*, *Tcd*)	Rice	[10]
Productivity	Genetic engineering (*GS3* for grain size, *CKX* for grain number, *DEP* for erect panicle)	Rice	[10]
High productivity and resistance to blast, bacterial leaf blight	Marker-assisted breeding	Rice	This review
Brown planthopper resistance	Marker-assisted backcross	Rice	This review
Aromatic rice	Marker-assisted breeding		This review
Grain yield	Mutation breeding confirmed by molecular markers	Soybean	This review
Grain yield (long juvenile varieties under short photoperiod)	Marker-assisted breeding	Soybean	This review
Virus (ChiVMV, Geminivirus)	Mutation breeding confirmed by molecular markers	Chili pepper	This review
Anthracnose	Breeding confirmed with molecular markers	Chili pepper	This review
Fusarium	Breeding confirmed with molecular markers	Shallot	This review

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To increase capacity for breeding, the IAARD continues to develop collaborative research network in terms of (1) developing genomic database facilities of prioritized commodities to strengthen breeding program and related applied technology, (2) maintaining facilities for genomic technology development, (3) improving human resource competency on bioinformatics, breeding and genomics, (4) strengthening scientific networking and scientist's capability on molecular breeding with emphasis on bioinformatic analysis, and (5) mainstreaming the genomic and genetic research, development and application/technology in agricultural technology development for strengthening national economy and food sovereignity. Taken together, sustainable use of GR for crop improvement, environmental policy along with the internationalization of science and technology in Indonesia have to be achieved through high effort.

5. Concluding remarks

A clear vision of future research, highlighting opportunities and challenges, is one primary concern in crop improvement. An efficient development in crop improvement through conventional breeding supported by gene and genomic technologies, genetic engineering and genome editing would increase the prospect of the utilization of PGR in Indonesia. The IAARD has contributed to improved varieties and technology transfer. A well-designed strategy that considers emerging technologies and timely development ensures that sustainable production of food, feed, fibre, and fuel in the future could be achieved. National strategic crops improvement of desired traits by employing advanced biotechnology could be a solution to challenges raised in Indonesia.

6. References

[1] Kern M 2002 Food, feed, fibre, fuel and industrial products of the future: challenges and opportunities. Understanding the strategic potential of plant genetic engineering *J. Agron. Crop Sci.* **188** 291–305
[2] Von Rintelen K, Arida E and Hauser C 2017 A review of biodiversity-related issues and challenges in megadiverse Indonesia and other Southeast Asian countries *Res. Ideas Outcomes* **3** 1–16
[3] Lestari P, Kim S K, Reflinur, Kang Y, Dewi N and Lee S 2014 Genetic diversity of mungbean (*Vigna radiata* L.) germplasm in Indonesia *Plant Genet. Resour.* **12** S91–4
[4] Food and Agriculture Organization 2007 *Adaptation to Climate Change in Agriculture, Forestry and Fisheries: Perspective, Framework and Priorities* (Rome)
[5] Fund C, B El-Chichakli, Patterman C and Dieckhoff P 2015 *Bioeconomy Policy (Part II)–Synopsis of National Strategies around the World. Report from the German Bioeconomy Council* (Berlin)
[6] Azadi H, Ho P and Hasfiati L 2011 Agricultural land conversion drivers: a comparison between less developed, developing and developed countries *L. Degrad. Dev.* **22** 596–604
[7] ASEAN Centre for Biodiversity 2010 *ASEAN Biodiversity Outlook* (Philippines: Dolmar Press, Inc.)
[8] Mulyani A and Agus F 2017 Kebutuhan dan ketersediaan lahan cadangan untuk mewujudkan cita-cita Indonesia sebagai lumbung pangan dunia tahun 2045 *Anal. Kebijak. Pertan.* **5** 1–17
[9] Eivazi A R, Naghavi M R, Hajheidari M, Pirseyedi S M, Ghaffari M R, Mohammadi S A, Majidi I, Salekdeh G H and Mardi M 2007 Assessing wheat (*Triticum aestivum* L.) genetic diversity using quality traits, amplified fragment length polymorphisms, simple sequence repeats and proteome analysis *Ann. Appl. Biol.* **152** 81–91
[10] Mulya K, Lestari P, Reflinur and Sabran M 2016 Genomic based crops improvement to support GSIAD 2015–2045 *Pre-Breeding and Gene Discovery for Food and Renewable Energy Security* ed M Sabran, P Lestari, K Kusumanegara and J Prasetiyono (Jakarta: IAARD Press) pp 33–41
[11] Setia R C and Setia N 2008 The omics technologies and crop improvement *Crop Improvement: Strategies and Applications* ed R C Setia, H Nayyar and N Setia (New Delhi: I.K.

International Publishing House Pvt. Ltd.) pp 1–18
[12] Abdallah N, Prakash C and McHughen A G 2015 Genome editing for crop improvement: challenges and opportunities *GM Crop Food* **6** 183–205
[13] Lee J S H, Jaafar Z, Tan A K J, Carrasco L R, Ewing J J, Bickford D P, Webb E L and Koh L P 2016 Toward clearer skies: challenges in regulating transboundary haze in Southeast Asia *Environ. Sci. Policy* **55** 87–95
[14] Krismawati A and Sabran M 2016 Pengelolaan sumber daya genetik tanaman obat spesifik Kalimantan Tengah *Bul. Plasma Nutfah* **12** 16–23
[15] Sabran M 2016 Plant genetic resources management in Indonesia: conservation, uses, and policy *Pre-Breeding and Gene Discovery for Food and Renewable Energy Security* ed M Sabran, P Lestari, K Kusumanegara and J Prasetiyono (Jakarta: IAARD Press) pp 3–18
[16] Haussmann B I G, Presterl T, Parzies H K and Miedaner T 2004 Plant genetic resources in crop improvement *Plant Genet. Resour.* **2** 3–21
[17] Miglani G S 2017 Genome editing in crop improvement: present scenario and future prospects *J. Crop Improv.* **31** 453–559