A review of maize production and breeding in Indonesia

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Abstract. Maize is one of the main commodities in Indonesia and has a significant role in maintaining the availability of other products. Maize needs in Indonesia continue to increase so that Indonesian government trying to boost maize production to substitute the need for imported maize and to achieve the target of maize self-sufficiency. To support this program, the government made a number of policies in the field of agriculture specifically for the development of maize to attract farmers to plant maize by making some policies, adapted technology and utilize unused land. The purpose of this paper is to provide an overview of the conditions of Indonesia's maize needs and how the Indonesia achieved maize self-sufficiency to substitute import maize needs also provide an overview of Indonesia maize breeding development as well. Acceleration of rate production is taken through the application of supporting technologies such as Increasing cropping index (IP), expansion of new planting areas, mechanization, superior varieties and facilities; Provision of capital, counseling and assistance; Planting maize on intercropped land with young oil palm plants, including the use of new superior varieties and cultivation technology with the Integrated Crop Management approach. The development of maize in Indonesia faces many challenges in the field by various agroecology with sub-optimal land such as saline, dry, acidic, tidal swamps, peat swamps, and shaded by plantations. To answer those challenges in maize breeding some maize varieties have been released namely Semar, Srikandi, Lamuru, Sukmaraga, variant of HJ, JH and BIMA varieties, also varieties for specific adaptation and characteristic like JHANA (shade tolerant), JHARING (drought tolerant) and NASA-29 (prolific). In molecular breeding many markers already found to be associated to Downy Mildew Resistance (DWR) and for drougt resistance using QTL analysis and also identify patterns of spread of important maize diseases in Indonesia.

1. Introduction
Maize is one of the main commodities in Indonesia and has a significant role in maintaining the availability of other products. With the rapid development of the livestock industry in Indonesia, the need for maize which is the main component in feed rations has also increased. It is estimated that more than 55% of domestic maize needs are used for feed, while for food consumption only around 30%, and the rest for other industrial needs and seeds [1], [2]. Thus, the role of maize is more as an industrial raw material than as a food ingredient at this time. The high and low prices of animal feed, will greatly affect the price of livestock products, the increase in maize prices impact on rising animal feed prices, and result in increasing prices of eggs and meat.

About 30-40% of the main components of feed rations are maize, so availability is very important for the sustainability of feed production [3]. At present, the need for maize for animal feed in
Indonesia is 24,680 million tons and is used by 97 feed industries in Indonesia which are spread throughout Indonesia. The low role of local maize in meeting the needs of the animal feed industry makes maize with the highest import value after sugar and soybeans, so that the Indonesian government trying to boost maize production to substitute the need for imported maize and to achieve the target of maize self-sufficiency as stated in the 2015-2019 RPJMN. To realize this goal, the Indonesian government needs to issue policies in agriculture. Agricultural policies such as extensification and increasing plant productivity are the keys to increase Indonesia's maize production and to achieve maize self-sufficiency [4]. To support this program, the government made a number of policies in the field of agriculture specifically for the development of maize to attract farmers to plant maize and to utilize unused land [5]. Policies in trade are also made in order to protect farmers' maize harvests then [6].

The demand for maize will continue to increase, so that the high yield potential of promising varieties is always to be a priority. Variety is one of the important factors to increase maize production. The use of new superior varieties such as hybrids is needed in order to maintain the stability of maize production. Breeding activities for maize in Indonesia have been carried out for long time and there were many hybrid maize varieties have been used by farmers since 1985. The varieties produced by both government and private research institutions. The number of superior varieties released is one indicator of the success of agricultural development in a country. The role of biotechnology is also needed in order to accelerate the identification and selection of parent to produce superior crosses and also to study the disease on maize [7], [8].

The increasing of maize needs in Indonesia and the government's policies to achieve maize self-sufficiency targets as well as the development of Indonesian maize breeding became a lesson in creating the conducive agricultural system for the sustainability of maize productivity. The purpose of this paper is to provide an overview of the conditions of Indonesia's maize needs and how the Indonesia achieved maize self-sufficiency to substitute import maize needs also provide an overview of Indonesia maize breeding development as well.

2. Maize Production in Indonesia

The government's seriousness in increasing maize production is stated in the 2015-2019 RPJMN which continues to boost national maize production with agricultural policies that favor to the farmers. In addition to increasing domestic maize production, the development of maize is also directed towards achieving self-sufficiency and maize exports, where the maize self-sufficiency target is expected to be achieved in 2017. Some efforts to achieve these targets are: 1) Increasing cropping index (IP), expansion of new planting areas, mechanization, superior varieties and facilities; 2) Provision of capital, counseling and assistance; 3) Planting maize on intercropped land with young oil palm plants [9].

The harvested area component is one of the important components in calculating production. The increase in Indonesia's maize harvest area from year to year has fluctuated. The growth of maize harvest area for the period 1999 - 2018 or in the last two decades has increased with an average growth of 3% per year (Figure 2). In 2016 - 2018 there has been a significant increase in harvested area throughout Indonesia in the new government era. This shows the government's efforts to expand maize, especially by utilizing land that is temporarily not cultivated. In 2016 the maize harvest area increased significantly by 15.85%, some efforts to increase maize production through the UPSUS program. This program is mainly carried out by extensification planting area, such as in paddy fields, dry land, plantation land or forest edge lands planting areas by empowering community land, forest land (Perhutani / Inhutani / HTI, and Social Forestry, plantation land, abandoned land, ex-mining land, especially former coal mines [10]. In order to achieve 2017 maize self-sufficiency, which utilizes a number of unused lands spread throughout the territory of Indonesia. It was recorded during the two decades (1999-2019) of maize planting in Indonesia, the maize harvest area experienced a significant increase in the last 5 years, since 2014 until 2018. In 2014 the area of maize cultivation was 3.84 million ha and in 2018 to 5.73 million ha, there was an increase of 49.22% with annually average
about 12.30% by the increasing of harvest area the maize production also increase from 19,008 million tons / ha on 2014 to 30.06 million tons / ha on 2018 [11].

Acceleration of the rate of increase in production is taken through the application of supporting technologies, including the use of new superior varieties (VUB) and cultivation technology with the Integrated Crop Management approach. The results of the simulation analysis using a dynamic system model show that sustainable maize self-sufficiency can be achieved if key policies to increase maize extensification and productivity are carried out that are able to meet the needs with simulation results, exceeding the government's target, will increase about 7.6% by extensification and 11.2% by boosting productivity. Indonesian maize production increase 57.55% with annually average increase around 14.39%. In 2019, to reach the target production of 33 million tons / ha, Indonesian government plans to add more harvest area until 6.53 million ha (Figure 1 and 2) [12]. The maize extensification policy is considered to be the most reliable breakthrough considering the ability to produce maize varieties circulating in Indonesia both those released by agricultural R & D and the private sector are still not enough to reach the government's target. The IAARD also developed the application of the Integrated Crop Management (PTT) model approach to foster the farmers with the use of technological components according to land capacity.

![Figure 1. Development of maize harvest in Indonesia from 1993 to 2018, and the target of the Indonesian government in 2019](image1)

![Figure 2. Maize production in Indonesia from 1993 to 2018, and the target of the Indonesian government in 2019](image2)
To overcome the problems that arise due to the abundance of production as happened in 1997, the partnership approach was carried out by the government and the private sector to guarantee the purchase of farmers’ crops. The government cooperates with animal feed companies to take the farmers maize with competitive prices and BULOG as a government institution that is required to absorb the local farmers' maize production. the government also closes the maize import tap so that feed companies can take local maize maximally.

Indonesian government policy can be said to be successful in substituting domestic maize needs with the success of significantly reducing maize import figures from 2016 to 2018 with a total number of 9.2 million tons maize (2016 (2.2 million tons), 2017 (3.5 million tons) and 2018 (3.5 million tons) with a foreign exchange value around Rp. 31 trillion and achieve self-sufficient maize in 2017 then managed to export 372 thousand tons of domestic-produced maize in 2018 to neighbouring countries as well [13].

The development of maize in Indonesia faces many challenges in the field by the variety of newly cleared lands due to Indonesia’s diverse agroecology with sub-optimal land such as saline, dry, acidic, tidal swamps, peat swamps, and shaded by plantations [14] Not only land problems, the opening of new land also has an impact on the high number of pests and diseases events those result in decreasing agricultural production, thus it is very important to develop various types of maize which is able to adapt well in specific environments with biotic and abiotic effects. Genotype selection in specific environment also pest and disease screening become very important in the breeding process to produce tolerant maize plants.

3. Maize Breeding in Indonesia

Research and development of maize plants in Indonesia is carried out by government research institutions (Research Institute for Maize and Cereals (ICeRi) under coordination Indonesia Agency for Agriculture Research and Development (IAARD), Ministry of Agriculture and Sang Hyang Sri (State owned enterprises (BUMN) and some from universities and private companies such as PT Dupont-Pioneer, PT BISI, PT Syngenta etc. The development of the food crop industry is characterized by the development of new superior varieties (VUB) of maize which have advantages in terms of production, harvest time, pest and disease resistance, quality, and special adaptation for sub-optimum land. breeding high-yielding varieties like hybrid maize is one of the important efforts that can be done to increase maize production.

Variety assembly activities require adequate management of germplasm to ensure the availability of genetic diversity. The management of germplasm includes the activities of introduction, exploration, conservation, rejuvenation and utilization carried out by plant research centers and the seed industry. Introductions were mostly carried out by maize research institutes in Indonesia, most of the germplasm was introduced from other country by cooperation between international agency such as Cimmyt (Centro Internacional de Mejoramiento de Maíz y Trigo). Exploration activities are also carried out to collect local genetic maize throughout Indonesia.

Maize which is developed in Indonesia is mostly maize which is designated as animal feed ingredients and only a small portion is functional food. Maize feed that is widely used by farmers in Indonesia is hybrid maize. About 80-90% of the cultivated varieties are hybrid maize and only 10-20% are open-pollinated maize. Many reasons why most farmers choose to plant hybrid maize, in addition to their high productivity and are more resistant to pests and diseases, hybrid maize is also the most marketed by private companies in Indonesia, so the use of hybrid maize dominates maize in Indonesia rather than open-pollinated maize.

Maize breeding technology in government research institutes is currently using more conventional breeding, although they have started using technologies such as tissue culture and biomolecular technology, these two technologies are more used towards basic research to check and test, such as diversity analysis [15] and produce cellular level diversity in tissue culture. Conventional breeding to produce hybrids is mostly done using one-lane crosses and 3 lanes. Genetic grouping patterns with
analysis of genetic diversity are needed to find out the characteristics of each genotype formed so that it can be used for parent selection in hybrid assembly [16]. At present many studies of maize breeding use convergent breeding techniques, this breeding technique is used to fix all important characters in plants and select them in specific stress specific environments such as salinity stress, drought, acid soils and flooded land [17]. Another breeding technique used is mutation using gamma rays to produce diversity in the existing maize population and to change only certain characters using small radiation doses.

The hybrid maize varieties in Indonesia were first released in 1983 produced by PT BISI, namely the C-1 variety, which is a hybrid cross-top (hybrid topcross), which is a cross between a free-run population and a single cross from Cargill. Furthermore, in the 1980s PT BISI released the CPI-1, Pioneer released the P-1 and P-2 hybrids, and IPB released the IPB-4 hybrid. Initially the hybrid released in Indonesia was a double cross hybrid hybrid, but now more single cross hybrids and single cross modification. Single cross hybrids have high yield potential with more uniform plant phenotypes than double cross or peak cross hybrids. Cereals Research Institute (ICeRi) in early 2007 released two single cross hybrid maize varieties, namely Bima-2 Bantimurung and Bima3 Bantimurung, capable of producing 11 t and 10 t / ha dry shells, tolerant of downy mildew disease, and can adapt to Optimal or suboptimal land. The Food Crop Research and Development Center has also formed pools 1, 2, 3, 4, and 5. Recurrent selection in population improvement, which also involves self-generation generation selection (selfing), will help increase tolerance to inbreeding and increase population capacity to produce more vigorous and superior lines. Some researchers have reported the progress of maize selection using alternating repeated selection (resiprocal recurrent selection). From this repeated selection back and forth, the IAARD has produced three superior varieties of free-run maize and eight hybrids. Some of the ICeRi maize varieties those have been released were Semar, Srikandi, Lamuru, Sukmaraga, variant of HJ, JH and BIMA varieties with average yield potential ranging from 5-13.6 tons/ha. Many varieties also released for specific adaptation were JHANA (shade tolerant), JHARING (drought tolerant) and NASA-29 (prolific maize). Nasa 29 variety has many excellences such as high-yield reaching 11.9-13.7 tons/ha, easy to flake using machine and tolerant to downy mildew. In addition, this variety is also able to adapt from low to medium land.

4. Molecular technology on maize research in Indonesia

In maize, the prediction of hybrid appearance is an important consideration and has attracted a lot of attention over the years. Information on kinship among breeding materials plays an important role in selecting parents efficiently through plant breeding programs. Genetic diversity is an important thing to know in breeding planning, hybrid identification and germplasm. Especially in hybrid breeding, the introduction and exploitation of heterotic patterns is very important to maximize heterosis. To produce a new varieties it takes three to four years in the tropics region, and even then it does not guarantee release as a new variety. Therefore, breeders are interested in molecular marking technology that offers an opportunity to adopt technology on a large scale to improve selection efficiency, especially in cereal plant breeding like maize.

The breeding of maize by utilizing molecular biology technology in Indonesia began since Indonesia joined the Asian regional network in 1998, namely the Asian Maize Biotechnology Network (AMBIONET) consisting of five countries namely China, Philippines, Indonesia, Thailand and India. the activities included improvement in human resources, characterization and identification of downy mildew disease, and genetic diversity of maize line and successfully identifying downy mildew resistance using RFLP and SSR markers [18]. Selection of downy mildew strains of 40 lines with semi-artificial inoculation methods in five locations and two seasons in Indonesia [19]. MAS's activities have successfully interrogated the opaque-2 recessive gene on the Nei9008 strain and for the Mr-10 strain it still requires one MAS and cross-crossing. Other biomolecular activities include identification of drought resistance QTL in population F and RIL, strains downy mildew maize (Nei9008), as well as identifying genetic diversity between maize lines to assemble the heterotic group.
needed in hybrid formation. Utilization of molecular markers to accelerate the selection process and improve the efficiency of assembling new superior maize with special properties quite prospective.

The development of maize breeding with molecular biology technology has succeeded in identifying the quantitative character locus (QTL) with high priority to maize resistance to downy mildew (DWR) and the characterization of genetic diversity and homogeneity of elite lines that are useful for the development of hybrid maize. In addition, improvements are also being made to the quality of maize protein by interrogating the opaque-2 recessive gene into downy mildew maize lines. The quantitative character locus of several agronomic parameters that are linked to the character of drought resistance are also identified, but still need further study before fine mapping in the framework of MAS.

Many markers (RFLP and SSR) already found to be associated to DMR. Additive effect detected in QTL analysis showed that negative value was general lead toward CML 139 (susceptible parent) [19]. The major QTL identified by the RFLP markers were 15,47, 8,23 and csu95 strongly associated with the resistance of downy mildew to maize in Indonesia. one SSR markers which are in positions between bnl5.47 and bnl8.23, namely bnlg1154 and fourrrl SSRs which are in positions between bnl8.23 and csu95d, yaitummc0241, phi078, bnlg1702 and nc013. These markers also have strong associations with downy mildew disease in four locations in countries such as India, the Philippines, and Thailand [20].

QTL for drought resistance in maize has also been analyzed using RFLP marking data as genotyping data and the results of drought filtering in Purbolinggo in 2004. Some RFLP markers are associated with several agronomic characteristics for drought tolerance were root capacitance and weight of 100 seeds on F3 population, meanwhile on RIL genotypes drought tolerance characters were indentified on height and location of the cob, female male flowering interval, root capacitance and female flowering time [21].

Bio-molecular methods are also used to identify patterns of spread of important maize diseases in Indonesia. By utilizing molecular markers such as Simple Sequence Repeats (SSR) to identify and analyze bio-diversity of pathogens causing downy mildew. The results of the SSR data profile indicate that the genetic variability of pathogen collection in some endemic locations in Indonesia is quite high, the albino species that develop in Indonesia vary or more than one. Pathogenic species causing downy mildew in Indonesian maize plants are P. maydis, P. philippinensis and P. sorghi. [23].

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