Role of plant genetic resources in encountering climate change challenge

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Abstract. The world is encountering a global threat: climate change. It is estimated that the average air temperature will raise 3.7 - 7.8 °C by 2100. The possible impacts will vary, however, agriculture will be adversely affected marked with yield loss of staple crops such as rice and maize and altered post-harvest quality of horticulture products. On the other hand, the world Food and Agriculture Organization (UN-FAO) has set a target ‘zero hunger’ by 2030’, despite the five big challenges ahead: i) protracted conflict, ii) growing inequality, iii) rapid urbanization, iv) economic challenges, v) drought and natural disasters. The existing plant genetic resources, particularly the wild, neglected, and underutilized species has a great role and bears big potential to be exploited and targeted to achieve food and nutrition security, esp. in the densely populated regions with malnutrition problem e.g. in Asia and sub-Saharan regions. However, a key to future and sustainable crop production lies in the collection of crop and their wild relatives stored in ex-situ, or in-situ. This paper aims to explain the importance of plant genetic resources as well as the potential of some underutilized crops closely attributed with drought resistance, such as sorghum (Sorghum bicolor L. Moench), amaranth (Amaranthus sp.). These crops bear potential to support national food security program.

1. Introduction
The world is encountering a global threat: climate change. It is characterized by the increase of air temperature from 3.7°C up to 7.8°C on the earth’s surface by 2100. Moreover, the tendency of global warming is not obscure, which is noted with the rising of average global temperature up to 0.9 °C between 1880 and 2015. If there has been no intensive mitigation action applied, thus, the direct consequences have been forecasted: i) rising sea levels and the ice decline of Arctic sea; ii) changing weather patterns and extreme weather leading to shifted planting seasons; iii) water and food scarcity that altered post-harvest quality of horticulture products; iv) political and security risks exacerbating food security problem at the global level; v) human health risks including mental health illness; vi)
adverse impact on wildlife and ecosystem. Most of scientists agree that the Green House Gas (GHG) emissions and the burning of fossil fuels are the major contributors of the increasing of temperature on earth, which are majorly driven as a result of man-made industrial modern activities [1].

The demand for food is still increasing, particularly in feeding the world growing population by 2020, which means that human should put much more efforts in terms of providing more nutritious food both quantitatively and qualitatively [2]. The world Food and Agriculture Organization (UN-FAO) has set ‘a zero hunger by 2030’ or a kind of relative optimistic, although some challenges had been identified: i) protracted conflict, ii) growing inequality, iii) rapid urbanization, iv) the economic challenges: rising trade tensions and elevated debt levels, v) drought and natural disasters due to the kick boxing impact of climate change [3]. This is somehow not so easy to achieve mission, particularly due to drought and natural disasters or point v, that is very likely to increase the number of people at risk of hunger and undernourishment on sub-Saharan Africa, where almost 75% of their income had been spent to purchase carbohydrate food based [4]. Second, is the tendential changes in land suitability for agriculture production and a significant decline of crop land quality occurred in most of developing countries. As a descriptive example, a prediction of global temperature rise from 1.8 up to 4 °C would later on, affect the more frequency of extreme events, e.g. heat waves, droughts and lower soil moisture leading to a drier condition, esp. in the Mediterranean region. In temperate latitudes, contrastingly, higher temperatures would be predominantly benefitted agriculture and pastoral activities in terms of: a) an increasing number of pasture and grass lands; b) an extended length of crop’s growing period; and c) higher number of yield [5].

The current existing ‘Plant Genetic Resources’ (PGR), particularly the wild, neglected, and underutilized species has a great role and bears at the same time potential to be exploited and targeted to achieve food and nutrition security especially in the high populated regions with malnutrition problem such as in Asian and sub-Saharan regions. They harbor a vast array of genetic diversity and source of gene-recombination that can be further utilized to encounter environmental stress factors and tackle the climate change challenges [6]. However, a key to future and sustainable crop production lies in the collection of crop and their wild relatives that are stored in external facilities e.g. gene bank (ex-situ) or from their natural habitat (in-situ). Their incorporation in any breeding attempts through specific allele recombination via conventional- or/and molecular-breeding techniques should be prioritized.

Simply stated, plant breeding activity depends highly on the correct combination of 50 up to 60,000 genetic loci found in a plant’s genome, which is similarly comparable with finding a needle in the stack of hay. Thus, finding the right combination, having the knowledge to discover the best and precise location of the desired alleles on specific loci on the chromosome arms, and finally creating the right blend of recombined genes in one single species can be considered as the ‘natural art’ in breeding science. Breeding cycles, itself, is an ‘on-and-on’ process and divided into seven major activities: 1) setting up major breeding targets for enhancing specific traits e.g. for foliage yield increase or any quality related characters, 2) genetic diversity assessment and characterization from available (genetic) variability or core collection, 3) selection of desired parental lines based on performed character on the field, 4) incorporation of desired traits or assembling of specific allele recombination via conventional (crossing, hybridization) or advance breeding technique, which is further known as ‘Marker Assisted Breeding’ (MAB), 5) incorporation of specific allele to their progenies until they are stable, 6) field performance tests on various sites, and finally 7) the release of novel breeding variety with enhanced character from their previous parental generation [7]. In regard to point 2), therefore, the aim of this paper is to explain the importance of two underutilized crops: amaranth (Amaranthus sp.) and sorghum (Sorghum bicolor L. Moench) that are closely attributed with drought resistance.

2. Materials and Method
Amaranth and sorghum classified as two heat tolerant crops were highlighted. One of the author had conducted her own amaranth study. She collected two sets of collection: the Indonesian- and worldwide-ones. A set of Indonesian collection (40-50 accessions) was collected mainly from Sumatra and Java on her own. The worldwide collection (32 accessions) was freely distributed from the Agriculture Research
Station (ARS)-USDA Plant Introduction Station at Iowa University, U.S.A. The morphological variation of Indonesian amaranths in comparison with the worldwide collection [8], their nutritional assessment emphasizing the protein and essential amino acids [9], their polyploidy level [10] had been published, elsewhere. This study tried to summarize the works in amaranth and compile major information about sorghum based on some literatures.

3. Results and Discussion
3.1. Amaranth (Amaranthus sp.)
Amaranth is widely grown on the equatorial belt of tropical African and Asian continent and majorly consumed as leafy vegetable. It is still classified as underutilized crop a serves as cheap source of protein and mineral, especially for rural low income communities, or for young children due to its high lysine content. Their popularity in South East Asia regions is comparable to that of water spinach (Ipomoea aquatica L.) and 'pak coy' (Brassica rapa subs. Chinensis) [8].

The genus consists up to 70 species, but only 15 of them are classified as edible. A high number of the species is still classified as invasive weeds, e.g. A. retroflexus and A. palmeri S. Watson. The latter is closely associated with the glyphosate resistance in vast cotton and soybean plantation [11]. A. caudatus, A. cruenthus, A. hypochondriacus are the most prominent grain species, while A. tricolor L. as the vegetable one (Figure 1). The taxonomical classification and genetic relationship among the species are sometimes still debatable, due to wide range of morphological diversity. Such phenomenon is a result of relatively high outcrossing (up to 10% in some cases) and polyploidy [6].

In most of temperate regions likewise U.S.A., northern Europe, the white seeded amaranth is consumed as an alternative food for person with celiac disease, or those who have higher hypersensitivity against maize-gluten. Historically, amaranth was originated and domesticated in the central and southern regions of American continent about 6,000 years old ago. The grain of amaranth was an integral part of the ancient cultures of the Aztecs and the Incas’ civilization in the ancient time, while it was grown on vast area of plantation in Mexico during the 14th century. However, its cultivation was strongly prohibited after the Spanish invasion to the New World in the 15th-17th centuries. The loss of grain amaranth in its domestication origin has made its taxonomic and phylogenetic study to be more complicated; compared to maize and beans [12]. The white and black seeded amaranths were then introduced to Asia by land routes and sea voyager around early 1700’s [6].

![Figure 1. Grain amaranth (A), green variegated amaranth (B), white seeded amaranth consumed as cereal, sorghum (D).](image-url)
In the tropics, leafy vegetables are accounted as valuable sources of vitamin, minerals, and protein. The average content of protein and lysine varies from 11 up to 31% Dry Weight Matter (DWM) depending on types, species, plant maturity stage and 5-7% g 100 g-1 DW protein, respectively [9]. Thus, a daily intake of at least 100 grams fresh green per person per day is highly recommended. The superiority of amaranth in terms of their nutrition [9], [6] and nutraceutical values [13] had been highlighted. These all support the nutritional superiority compared to the other three common cereal grains with high protein, e.g. soybean (Glycine max), quinoa (Chenopodium quinoa spp.), and buckwheat (Fagopyrum esculentum). Furthermore, it is also worth to be noted that the relatively high protein content in amaranth is highly soluble and more suitable as functional foods [14].

Here, we would like to highlight other aspect of amaranth in terms of its high drought and heat tolerance. Thus, such distinguished features would elevate amaranth’s position previously as neglected crop to one of the potential food crops for encountering climate change thanked to its remarkable feature as a C₃-plant that is proven to be more efficiently in utilizing input, and thus can sustain high photosynthetic activity [14]. In the Indo-Gangetic Plains, where there is a sharp amplitude between summer called as ‘Kharif’ and winter temperature, vegetable amaranth is known as the only vegetable crop that can endure temperature up to 45 °C [15]. Similar field experiences related to drought-, heat-tolerance in Taiwan [16], and amaranths’ performances featuring their saline or poor fertility soils tolerance were also highlighted [12].

Given the wide array of genetic variation, wide adaptability, and low agricultural input, this crop is an ideal choice in crop diversification program in order to challenge the climate change. Nevertheless, its adoption from its regular status as an ‘orphan crop’ into a more promising level or as an ‘improved’ one should be overcome via hybrid breeding method strategies [6].

3.2. Sorghum (Sorghum bicolor L. Moench)
Sorghum is believed to be originated from Africa and serves as a vital subsistence crop for rural populations in semi-arid regions. It is the 5th most important cereal after rice, wheat, maize, and barley and provides grain for over 750 million people living in the semi-arid tropics of Africa, Asia, and Latin America. It is also a short day C₃ plant with an outcrossing rate up to 6% depending on the genotype and environment condition [17]. It is generally grown in semi-arid regions, where it is too dry or too hot for successful maize production. Their heat resistance could endure a temperature above 38 °C. Such distinct features and good plant adaptation to the drier climates are due to several factors; likewise: 1) the ability to remain dormant during drought and then resume growth; 2) leaves roll up as they will reduce the area of leaf exposed for transpiration; 3) leaves and stalks contain an abundance of waxy coating, which enable plant to be protected from drying; 4) they exhibit a low transpiration ratio, meaning the amount of water required (in kg) to produce a kg of plant material. They are 141 kg, 170 kg, 241 kg for sorghum, maize, wheat, respectively; 5) plants have a large number of fibrous roots that efficiently extract moisture from the soil, therefore, root length may be up to 2.5 m; 6) a large root absorption area and relatively large area [18].

Still, it is classified as one of the remaining few crop species, whose extensive genetic variability is still existed. Up to 36,719 accessions of sorghum collection consists of traditional varieties including landraces (84.3%), breeding lines (14.5%), wild species (1.1%) are being held by the International Crop Research Institute for the Semi-Arid and Tropics (ICRISAT). It is generally classified based on its grain color: white, red, to brown sorghum [19]. In fact, the cultivated sorghums are highly variable and perform more relatively distinct features e.g.: plant height [cm], number of nodes, panicle length [cm], tillering, days to panicle emergence, days to flowering, 100 kernel weight in gram [g], weight of grains per plant [g] - as a result of a domestication process; compared to those more isolated ones [20].

The largest group of sorghum producers is small-scale subsistence farmers. They tend to select varieties attributed with the characteristics of resistance to insects, disease, drought, birds, relatively low yields; namely in the range of 0.3 -1.0 tons/ ha used for grain or human consumption and fodder for livestock feed. Despite a relatively low yield in traditional varieties; compared to those commercial ones (up to 12 tons/ ha), they are more sustainable under environmental conditions, which would make maize
production unfeasible. Most of subsistence farmers are aware that new high yielding varieties are more susceptible to pest and disease attacks [18]. In 1995, there are almost 44 millions of hectares land planted with sorghum worldwide, with almost 50% of them are found on the African continent. It is mostly consumed as porridges, malted flours for brewing and further consumed as alcoholic beers, or as weaning foods for infants and children. Some of them are also consumed in similar way to that of rice on Kenya and South Africa. It is highly nutritious as its protein, calcium and vitamin B1 are higher than the values found in rice and corn while, calorie and carbohydrate are nearly equivalent with the two staple crops or even better as it contains less fat [21]. Despite of this, major purpose of sorghum utilization is predominantly for livestock or feeding industry with the major producers of sorghum are the USA, Argentina, and Australia [20].

In Indonesia, sorghum has not yet been included as a priority crop in encountering climate change. Although some areas in Indonesia ranging from 6 to 870 ha and these are attributed with savanna climate representing the driest part of Indonesia (the West and East Nusa Tenggara) or with unirrigated fields of Central and East Java, Special Region of Yogyakarta, have already started to grow sorghum as a food based alternative, as raw material in the production of Monosodium Glutamate (MSG) [22], as bioethanol plant [23]. In short, we can conclude that sorghum is closely associated as a high productive plant with low risk of failure, low cost, pest resistant, a very minimum amount of water requirement, and very suitable to be planted on dry land or paddy fields during the dry season [21].

4. Conclusion

Agriculture is under great pressure to produce greater quantities of food on limited land resources for the projected nine billion of global population by 2050. It has been estimated that agricultural production is urged to increase 70% in order to fulfill the raise of 40% of world population by 2050. Such circumstances are being exacerbated with the threat of climate change. In this regard, Plant Genetic Resources (PGR) could be undertaken as a proper solution in encountering the global challenges. Here, under-utilized crops e.g. amaranth and sorghum have been prospected due to their untapped great potential to be applied as alternative food crop in encountering the climate change

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