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Review Article

Role of Crop Research and Development in food Security of Africa

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Abstract

Food security is the main concern in Africa as the production and productivity of crops are under continuous threat. Indigenous crops also known as orphan- or as underutilized- crops provide key contributions to food security under the present scenario of increasing world population and changing climate. Hence, these crops which belong to the major categories of cereals, legumes, fruits and root crops play a key role in the livelihood of the resource-poor farmers and consumers since they perform better than the major world crops under extreme soil and climate conditions prevalent in the continent. These indigenous crops have the major advantage that they fit well into the general socio-economic and ecological context of the region. However, despite their huge importance, African crops have generally received little attention by the global scientific community. With the current production systems, only a fraction of yield potential was achieved for most of these crops. In order to devise strategies towards boosting crop productivity in Africa, the current production constraints should be investigated and properly addressed. Key traits known to increase productivity and/or improve nutrition and diverse conventional and modern crop improvement techniques need to be implemented. Commitments in the value-chain from the research, production, marketing to distribution of improved seeds are required by relevant national and international institutions as well as African governments to promote food security in a sustainable manner. The review also presents major achievements and suggestions for stakeholders interested in African agriculture.

ABBREVIATIONS

AAAPD: Association of African Agricultural Professionals in the Diaspora; ADP: African Diaspora Program; AR4D: Agricultural Research for Development; ASTI: Agricultural Science and Technology Indicators; AFAAS: African Forum for Agricultural Advisory Services; CGIAR: Consultative Group on International Agricultural Research; FAO: Food and Agriculture Organization; GCARD: Global Conference on Agricultural Research for Development; GDP: Gross Domestic Product; GFAR: Global Forum Agricultural Research; GFRAS: Global Forum for Rural Advisory Services; IDA: Iron Deficiency Anemia; IFAD: International Fund for Agricultural Development; R&D: Research and Development; VAD: Vitamin A Deficiency; WFP: World Food Program

INTRODUCTION

Food security is defined as a situation that exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life [1]. According to FAO [2], food security is based on four pillars:

i) *food availability* which refers to the availability of sufficient quantities of food on a consistent basis

ii) *food access* which refers to having sufficient resources, both economic and physical, for acquiring appropriate food for a nutritious diet

iii) *food utilization or quality* which refers to the appropriate use of food based on knowledge of basic nutrition and care, as well as adequate water and sanitation

iv) *Stability* which refers to availability and accessibility of quality food at all times.

The report on the State of Food Insecurity in 2012 [3], reveals that about 870 million people are chronically undernourished and that the majority of them live in developing countries. The same report indicates that Africa has the highest proportion of its population (23%) undernourished followed by Asia (14%) and Latin America (8%).Although large proportions of Africa's populations are engaged in agriculture, the produce from this sector cannot feed its citizens. Hence, many African countries are obliged to import large quantities of grains and oil seeds every

year. The top three import items for Africa in the year 2011 were wheat (42 million tons), maize (15 million ton) and soybeans (8 million ton) which cost a total of 25.8 billion USD (15.5 billion USD for wheat, 4.6 billion USD for maize and 5.7 billion USD for soybeans) [4]. This indicates that every year African governments spend a large amount of their budget to satisfy the demand for food. Inflation of food prices, particularly in 2008 and 2011, elevated the price of wheat up to 40% and that of soybeans up to 70% in a single year [4] which exposed African countries to extremely high and unplanned expenditures. According to Fahey [5], food security could be improved by focusing on indigenous and economically important crops in addition to the major crops of the world. The need to focus on orphan crops in order to meet the need for food demand was emphasized [6, 7].

CHALLENGES TO FOOD SECURITY IN AFRICA

Various constraints affect the production and distribution of food crops in Africa. Among these, the major ones are briefly discussed below.

Dynamic changes in African demography

The African population has been growing at a very high rate and is expected to grow to2.4 billion by 2050, more than doubling the current 1.1 billion. This 120% increase in only 36 years will bring additional 1.3 billion people to inhabit the continent. The main worry is whether every citizen of the continent will be able to obtain the basic needs of a human being, particularly food. Although at the present time approximately 60% of African population lives in rural areas, the trend is expected to change after 2035 after which more people will live in urban areas, although there is no indication for the provision of enough infrastructure and jobs for new city dwellers. In addition to the large percentage of unemployed in Africa, conditions are worsened by the fact that only 35% of the rural and 47% of the urban population are economically active at the present time [4].

It is expected that with the current level of crop productivity, it might be difficult to feed the African population. According to Tilman *et al.* [8], the demand for global food is rising rapidly with about a 100%-110% increase in crop demand expected from 2005 to 2050. In general, there is big gap between increases in population and crop production.

Economically active populations in Africa are substantially affected by health-related problems. Diseases such as HIV/AIDS, malaria, tuberculosis and diarrhea continue to affect a large percentage of the working population. According to the World Health Organization [9], Sub-Saharan Africa with only 11% of the world population, constitutes 60% of HIV/AIDS and 90% of malaria cases. Neglected diseases such as sleeping sickness (or African Trypanosomiases) also affect the productivity of a large number of people in locations where these diseases are significant.

In general, although a large percentage of the African population is affected by shortage of food and malnutrition, due to the high rate of population growth and the lack of infrastructure and job opportunities, the situation will be aggravated unless proper policy measures are taken. According to Losch [10], although presently the number of new job seekers per year in Africa is already high, i.e., 10 million per year, the figure will double by 2030.

Scarcity of investment in research and capacity building

Compared to other regions of the world, little investment has been made in agricultural research in Africa. Indigenous crops, commonly known as orphan- or underutilized crops, play an important role in the economy of the continent as they provide nutrition to large number of people and also provide income for small scale farmers. According to Crops for the Future [11], the diverse names given to these crops reflect the following characteristics: 'neglected' (by science and development), 'orphan' (without champions or crop experts), 'minor' (relative to global crops), 'promising' (for emerging markets, or because of previously unrecognized value traits), 'niche' (of marginal importance in production systems and economies), and 'traditional' (used for centuries or even millennia).

The famous Green Revolution contributed to a significant boost in crop production and productivity in Asia but did not occur in Africa, mainly due to the exclusion of major African crops as a primary focus of improvement [7,12]. In terms of area of cultivation, the top three crops in Africa are maize, sorghum and millet, while in Asia they are rice, wheat and maize in descending order (Figure 1, [4]). In Africa, cereals produce inferior yield while root crops such as cassava (manioc; *Manihot esculenta*) and yam (*Dioscorea sp*) which are associated with a high risk of post-harvest losses due to short shelf-life contributed to the bulk of production. On the contrary, the major cereal crops in Asia can be stored for long periods of time, at least until just before the next cropping season which corresponds to the critical time of food shortage.

Investment in research and development especially in human resources and infrastructure are also low in Africa. Although African countries agreed to allocate at least 10% of their national budgetary resources to agriculture and rural development policy implementation, only few of them have reached the target [13].

Prevalence of widespread environmental stresses

In Africa, crop productivity is affected by a variety of a biotic and biotic stresses. Major a biotic stresses are drought, soil salinity and soil acidity. In recent decades, agricultural land has been lost to desertification, salinization, soil erosion and other consequences of unsustainable land use [12]. Biotic factors such as diseases, insects and weeds also induce significant crop loss. Their adverse effects on crop productivity are more obvious in the tropics than in the temperate climates because the tropical environment is conducive to the presence of crop nuisances in high density and diversity throughout the year. Commonly practiced cropping systems in Africa, especially the multiple cropping systems in which several crops share the same piece of land at the same time, provide suitable conditions for the long-term presence and infestation of crop pests and diseases.

PROSPECTS OF AFRICAN CROPS IN FOOD SECURITY

Crops grown in Africa belong to the main categories of crops

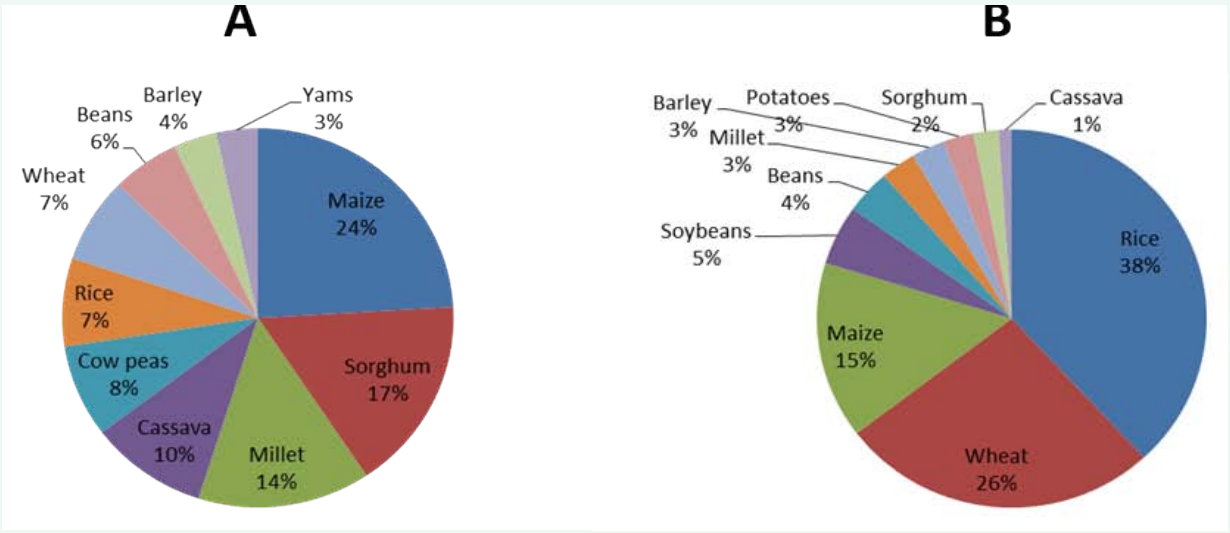

Figure 1 The proportion of the top ten crops grown in Africa (A) and Asia (B) in terms of area. Africa missed the famous Green Revolution which was implemented in Asia on rice and wheat—these two major crops are annually cultivated on 60% of the land of devoted to the top ten crops in Asia as opposed to only 14% in Africa. Adapted from FAOSTAT [4].

which include cereals, legumes, vegetables, root crops and fruits. Although similar types of crops are cultivated in Africa and the rest of the world, Africa has some unique crops which are solely cultivated and consumed in the continent. The main benefits of African crops are briefly discussed below.

Agronomic benefits

African cereals have a number of advantages in terms of adapting to extreme climatic and soil conditions. For instance, finger millet(*Eleusine coracana*) is especially adapted to drought [14]. Tef (*Eragrostis tef*) is also tolerant to abiotic stresses especially to poorly drained soils where other crops such as maize and wheat do not survive [15]. Fonio (*Digitaria exilis* and *D. iburua*)is not only drought tolerant but is also a very fast maturing crop [14, 16].African rice (*Oryza glaberrima*) is mostly cultivated in West Africa especially in drought-prone areas and on impoverished soils[16]. Due to their early maturing properties, most of these crops are the source of food during critical food shortage periods, particularly the time just before most crops are ready for harvest.

Cowpea is tolerant to drought and heat, and performs better than many other crops on sandy soils with low levels of organic matter and phosphorus [17]. Since cowpea grows quickly, bringing about rapid ground cover, it is a useful crop in controlling erosion [18]. Grass pea (*Lathyrus sativus*) is also extremely tolerant to drought and is considered as an insurance crop since it produces reliable yields when all other crops fail. Similar to cereals and legumes, some root crops cultivated in Africa are known to withstand extreme environmental conditions. Among these, cassava is tolerant to drought, and also performs better than other crops on soils with poor nutrients. Enset (*Ensete ventricosum*) is the major food for over 10 million people in the densely populated regions of Ethiopia where it is considered as an extremely drought tolerant crop that adapts to different soil types [19].

Nutritional and health benefits

African cereals are rich sources of nutrients for both humans and animals. The seeds of finger millet contain valuable amino acids especially methionine [16], which is lacking in the diets of hundreds of millions of the poor people who live on starchy staples such as cassava. Finger millet is also a popular food among diabetic patients because of its low glycemic index and slow digestion [20]. The seeds of fonio are nutritious especially in methionine and cysteine, the two amino acids essential for human health but deficient in major cereals such as wheat, rice and maize [21].In addition to their significant economic importance, African crops provide nutritive and healthy diet. For instance, finger- and pearl-millets have an anti-proliferative property, and might have a potential in the prevention of cancer initiation [22]. Tef, a cereal crop mainly grown in the Horn of Africa, is considered a healthy food since the seeds do not contain gluten [23], the cause for celiac disease.

Food legumes are the major source of protein for African consumers. Among these, the seeds of bambara groundnut (*Vigna subterranean*)is unique since they contain adequate quantities of protein (19%), carbohydrate (63%), and fat (6.5%) [24]. Like other grain legumes, grass pea is a source of protein particularly for resource-poor farmers and consumers. Among fruits in Africa, banana especially the orange pulped type with high carotenoid and iron content could reduce Iron Deficiency Anemia (IDA) by over 50% and also Vitamin A Deficiency (VAD) in East Africa, where both IDA and VAD affect a large percentage of the population [25].Both banana and plantain are considered to be healthy foods, and are also rich in essential nutrients for humans.

As the grains are the main food source of humans, crop residues particularly the straws from cereals are invaluable source of livestock feed. The straws from tef are more palatable and nutritious than those of wheat and barley; hence, they fetch higher prices[26].

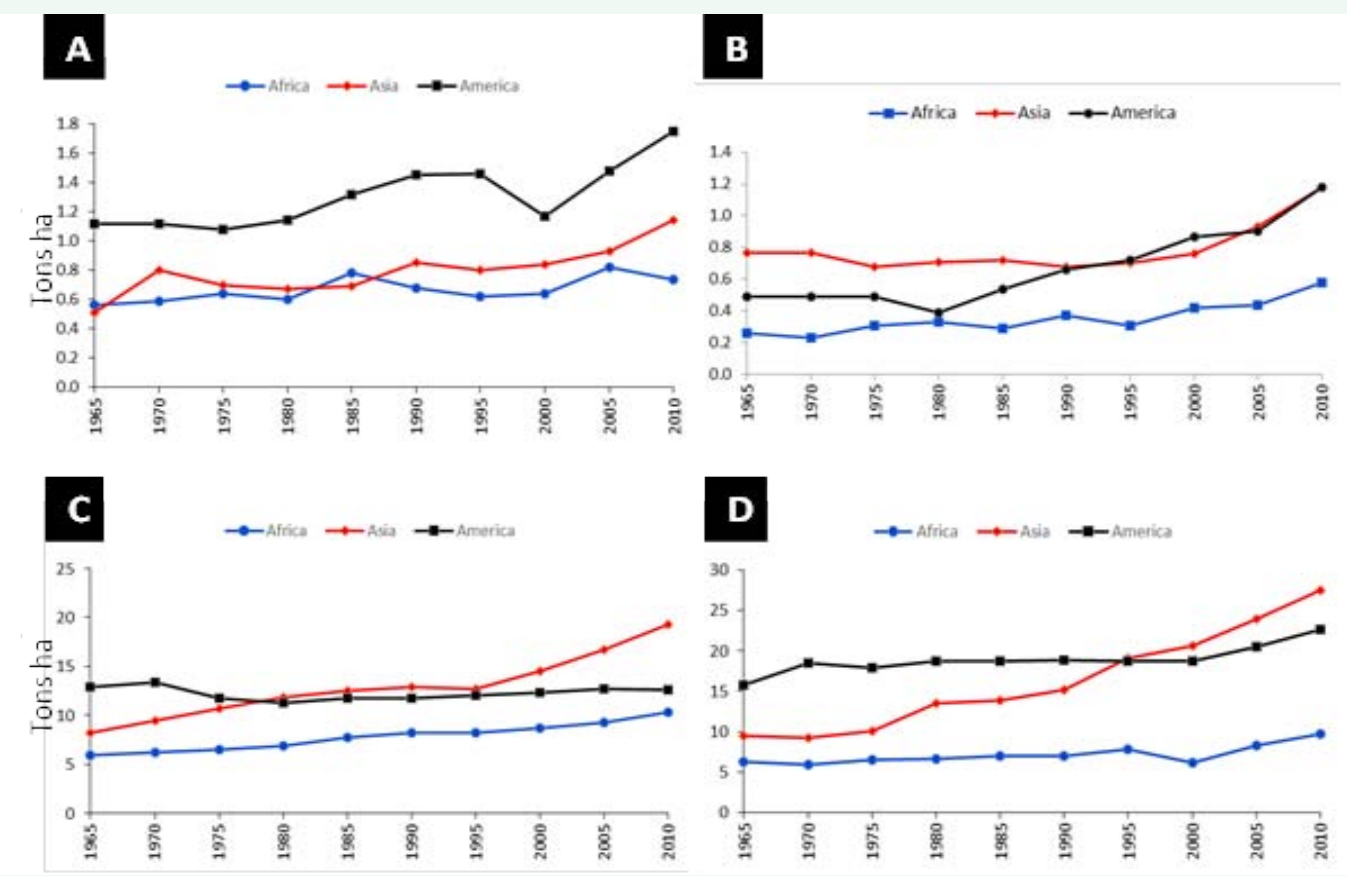

Figure 2 Crop productivity is low in Africa (blue) compared to Asia (red) and Latin America (black). The average yields of A) millet, B) cowpea, C) cassava, and D) banana from 1965 to 2010 in the three continents. The four crops, which are cultivated in all three continents, represent the major crop groups, namely cereals, legumes, root crops and fruits. Adapted from FAOSTAT [4].

THE WAY FORWARD: SUGGESTIONS TO STAKEHOLDERS

Due to the diverse socio-economic conditions prevailing in Africa, some recommendations could not be generalized. However, the key points which are relevant for most countries are indicated below.

Develop improved seed with high productivity

Although African crops possess many desirable agronomic and nutritional properties, they are not blessed with everything. Due to little genetic improvement, most of these crops produce inferior yield in terms of both quality and quantity. Although from the global area, 67% of cassava, 43% of sweet potato, and 30% of banana are grown in Africa, the contribution of these crops to the world production are only 52% for cassava, 17% for sweet potato and 15% for banana [4]. These extremely low productivities in Africa are due to the prevalence of huge number biotic and abiotic stresses, the use of inefficient agricultural inputs, and policy-related problems.

The trend in crop productivity for the last 45 years has shown little improvement in Africa compared to Asia and Latin America. The yield of four crops, namely millet, cowpea, cassava and banana, which respectively represent cereals, food legumes, root crops and fruits were higher in other continents than in Africa where they are the dominant crops(Figure 2; [4]). The increases in productivity in Africa for the indicated period were only 32% for millet, 75% for cassava and 53% for banana. However, during the same period, productivity was raised in Asia by 123% for millet, 134% for cassava, and 191% for banana.

Studies on the yield potential of some African crops revealed the possibility of raising the productivity several-fold by using improved genotypes and/or management (**Table 1**). In addition, focusing on crops with high efficiency in nutrient and water utilization is also useful.

Explore new areas for crop cultivation

In Africa, crop productivity is affected by a variety of biotic and abiotic stresses. Large areas of agricultural land have been lost to desertification, salinization, soil erosion and other consequences of unsustainable land uses [12].Global warming is also expected to negatively affect crop production. Recent studies showed that the rainfall has decreased by about 15% in the main growing-season in the eastern and southern Africa, creating drought and as a consequence, it is projected to increase the number of undernourished people by 50% in 2030 [27]. The prediction also indicates a decrease in rainfall in West Africa and an increase in temperature in the Sahel coastline[28]. According to Sarr [28], the most drastic effect of climate change on agriculture will be from the late onset and early cessation of rainfall, and the

Table 1: Potential yield and yield gap for selected crops in Africa.

Crop type	Average farmers' yield	Yield potential	Yield gap	Improved system	Location/region	References
	(ton ha^{-1})		(%)			
Cereals						
Millet	0.72	2.43	233	Genotypes and management	West Africa	[40]
Pearl millet	1.61	4.20	161	Genotype (dwarf type)	Samanko, Mali	[41]
	1.61	4.50	179	Genotype (early maturing)	Cinzana, Mali	[41]
Tef	1.20	4.60	283	Genotype (Dukem cultivar)	Debre Zeit, Ethiopia	[42]
Maize	1.24	3.40	174		West Africa	[40]
Rice	1.1	3.1	180	Phosphorus fertilizer	West Africa	[43]
	1.49	2.78	87		West Africa	[40]
Sorghum	0.84	2.75	227		West Africa	[40]
Legumes						
Beans	0.54	1.14	111		West Africa	[40]
Root crops						
Cassava	10.30	23.33	126	Management, genotypes & fertilizer	Uganda	[44]
	9.15	14.00	53	Genotypes and management	West Africa	[40]
Sweet potatoes	8.67	15.30	76		West Africa	[40]
Potatoes	6.11	28.40	365		West Africa	[40]
Fruits						
Banana	6.08	27.40	351	Genotypes and management	West Africa	[40]
	6.80	19.68	189	Management, genotypes & fertilizer	Kenya	[44]

consequent reduction of the growing period. Hence, developing crops that adapt to abiotic stresses and changing climate is vital.

Implement policy that favors productivity

In order to achieve a Green Revolution in Africa, locally appropriate development such as human and institutional capacity building as well as the formation of policies conducive to food security need to be implemented [7]. According to Horlings and Marsden [29], the real green revolution will be realized in Africa by implementing an ecological modernization process, which includes social, cultural, spatial and political aspects. African governments also need to implement land, marketing, and credit policies conducive to supporting agricultural development.

According to Agricultural Science and Technology Indicators (ASTI), African countries with the highest GDP in agriculture such as Botswana and Uganda also invested more in their agricultural human resources, as their spending per agricultural researcher and per capita were among the highest in the continent[30]. Surprisingly, Cote d'Ivoire with the highest expenditure per researcher had an extremely low number of agricultural researchers per million people.

Efficient use of agricultural resources and inputs

Poor crop productivity in Africa is also due to the use of inefficient agricultural practices, beginning from land preparation, weeding, harvesting and finally to threshing and storage. In addition, sub-optimal use of input such as fertilizers, herbicides and pesticides contributes to the low productivity of crops in the continent [31, 32].

Land and other vital resources are not efficiently utilized to enhance productivity and/or maintain the ecosystem. The fertility of the land and the land tenure system has huge impact on crop productivity. The proportion of land under arable- and permanent-crops is higher in Asia than in Africa indicating more land use in Asia. While the percentage of these crops reached up to 74% in Southern Asia, in Africa a maximum of 33% land was under these crops in the western Africa[4].The type of land tenure or ownership also affects crop productivity. Studies in Uganda indicated that secure land tenure is important since it provides incentives to small-scale farmers for the long-term investment which in turn promotes crop productivity [33].

Implement favorable and dynamic extension system

The transfer of new technologies to farmers is facilitated if the efforts are made towards solving major constraints and by involving farmers from an early stage of technology development since both enhance the acceptance of the technology. Involving farmers in seed production and distribution especially by providing incentives to those who are willing to produce and distribute clean seed to fellow farmers is necessary. Global Forum for Rural Advisory Services (GFRAS) promotes 'New Extensionist' which advocates the new roles of extension services in the changing world [34]. The organization plays a key role from the national to global level in organizing training, creating networking and developing policy briefs. By working with GFRAS and regional networks such as African Forum for Agricultural Advisory Services (AFAAS) [35] which is based in Kampala,

Uganda, African countries can learn about successful experiences of other countries or regions.

Create or strengthen partnership with stakeholders

Establishing a genuine partnership with national, regional and international institutions is important. In the writer's opinion, among the existing partnerships related to agricultural research and development, the one established at the global level between Global Forum Agricultural Research (GFAR) [36] and Consultative Group on International Agricultural Research(CGIAR) [37] is the most efficient. The two recent congresses organized by this partnership namely the Global Conference on Agricultural Research for Development (GCARD1) in 2010 in Montpellier, France; and GCARD2 in 2012 in Punta del Este, Uruguay attracted a lot of researchers, development workers, farmers, policy makers and donors. The main goal of GCARD2 was to move from WHY the transformation of AR4D is important, to HOW to implement the GCARD Road Map in practice and WHAT difference does it make [36].

Efficient use of resources and information

African countries need to benefit from resources from agricultural-related international organizations such as the Food and Agriculture Organization (FAO), the International Fund for Agricultural Development (IFAD) and the World Food Program (WFP) which allocate a large amount of their budget to the alleviation of food security problems in Africa. All of the 15 CGIAR centers have currently activities in Africa. A number of institutions or governments in developed countries are also interested in improving the livelihood of Africans through joint projects with researchers and development workers in these regions. In addition, non-governmental organizations annually pledge large amounts of financial and technical support for research and development activities in Africa.

African countries need to investigate existing information and harness it for proper use in devising policies or strategies. Africa has also a number of trained personnel in the continent or in Diasporas. Policy makers need to explore options on how to exploit the technical knowhow of these skilled personnel. Some agriculture experts of African origin currently living abroad have already started initiatives. The African Diaspora Program (ADP) [38] and the Association of African Agricultural Professionals in the Diaspora (AAAPD) [39]are among these initiatives.

CONCLUSION

African crops are vital contributors to food security in the continent particularly under the present scenario of increasing world population and changing climate as they have advantages in already fitting into the socio-economic and ecological contexts. However, despite their huge importance, African crops have generally received little attention by the global scientific community. In addition to rapid increases in population and the low productivity of indigenous crops, the cultivation of these food crops is constrained by huge and diverse biotic and abiotic stresses. In order to devise strategies towards boosting crop productivity in Africa, these production constraints need to be thoroughly investigated and properly addressed. The next Green Revolution, the one for Africa, needs to include locally adapted crops, which are mostly under-studied. Although these crops are largely unimproved, the implementation of modern improvement techniques to these crops has many advantages. It is not the intention of the author to advocate research and development of only orphan crops in Africa, rather to use them to complement the advanced systems developed for major crops such as wheat and rice. At the same time, major crops with high productivity could also be grown in areas suitable for their cultivation. Crop improvement by itself does not lead us to the final goal unless supported by policies that include extension, land tenure and credits. In general, strategies and policies conducive for boosting productivity need to be devised in addition to establishing partnerships with relevant stakeholders.

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REFERENCES

1. FAO, Trade reforms and food security: conceptualizing the linkages. . 2003, Rome: Food and Agriculture Organization (FAO). 296.
2. FAO, Food Security, in Policy Brief. 2006.
3. McGuire S. WHO, World Food Programme, and International Fund for Agricultural Development. 2012. The State of Food Insecurity in the World 2012. Economic growth is necessary but not sufficient to accelerate reduction of hunger and malnutrition. Rome, FAO. Adv Nutr. 2013; 4: 126-127.
4. FAOSTAT. Crop production. 2014
5. Fahey JW. Underexploited African grain crops: a nutritional resource. Nutr Rev. 1998; 56: 282-285.
6. Raheem D, The need for agro-allied industries to promote food security by value addition to indigenous African food crops. Outlook on Agriculture, 2011. 40: 343-349.
7. Ejeta G. African Green Revolution needn't be a mirage. Science. 2010; 327: 831-832.
8. Tilman D, Balzer C, Hill J, Befort BL. Global food demand and the sustainable intensification of agriculture. Proc Natl Acad Sci U S A. 2011; 108: 20260-20264.
9. WHO, The African Regional Health Report: The Health of the People, in Bulletin of the World Health Organization 2014. p. 170.
10. Losch, B, Need for Inclusive Agricultural Growth at the Heart of Africa's Economic Transition. Challenges in African Agriculture ed. J.J. Deveze. 2011, Washington DC: World Bank.
11. CFF. Crops for the future
12. Godfray HC, Beddington JR, Crute IR, Haddad L, Lawrence D, Muir JF, et al. Food security: the challenge of feeding 9 billion people. Science. 2010; 327: 812-818.
13. AU. 10 Percent National Budget Allocation to Agriculture Development: Maputo Declaration on Agriculture and Food Security. 2005
14. Williams JT, Haq N, Global research on underutilised crops: an assessment of current activities and proposals for enhanced cooperation. 2000: Southampton, 50.
15. Ketema, S, Tef, Eragrostis tef (Zucc.) Trotter. 1997, Institute of Plant Genetics and Crop Plant Research, Gatersleben/International Plant Genetic Resources Institute: Rome, Italy. 52.
16. NAP, Lost Crops of Africa, Volume I: Grains. National Academy Press,

Washington, D.C. 1996

17. Sanginga, N., O. Lyasse, and B.B. Singh, Phosphorus use efficiency and nitrogen balance of cowpea breeding lines in a low P soil of the derived savanna zone in West Africa. Plant and Soil. 2000; 220:119-128.

18. Valenzuela H, Smith J, Cowpea, in Sustainable Agriculture, Green Manure Crops. 2002. p. 3.

19. Brandt SA. The "tree against hunger": enset-based agricultural system in Ethiopia. 1997; Washington, D.C: American Association for the Advancement of Science. 56 p.

20. Chandrashekar A. Finger millet: Eleusine coracana. Adv Food Nutr Res. 2010; 59: 215-262.

21. IPGRI, Promoting fonio production in West and Central Africa through germplasm management and improvement of post harvest technology. 2004; 18.

22. Chandrasekara A, Shahidi F. Antiproliferative potential and DNA scission inhibitory activity of phenolics from whole millet grains. Journal of Functional Foods. 2011; 3: 159-170.

23. Spaenij-Dekking L, Kooy-Winkelaar Y, Koning F. The Ethiopian cereal tef in celiac disease. N Engl J Med. 2005; 353: 1748-1749.

24. NAP, ed. Lost Crops of Africa; volume II: Vegetables. 2006; National Academies Press.

25. Fungo R. Potential of bananas in alleviating micronutrient eficiencies in the great lakes region of East Africa. African Crop Science Conference Proceedings. 2009; 9: 1- 8.

26. Yami A, Tef straw: a valuable feed resource to improve animal production and productivity, in Achievements and prospects of tef improvement. Assefa KS, Chanyalew, Tadele Z. 2013; 233-251.

27. Funk C, Michael D, James PV, Molly EB, Mathew B, Andrew H, et al. Warming of the Indian Ocean threatens eastern and southern African food security but could be mitigated by agricultural development. Proceedings of the National Academy of Sciences of the United States of America. 2008; 105: 11081-11086.

28. Sarr B. Present and future climate change in the semi-arid region of West Africa: a crucial input for practical adaptation in agriculture. Atmospheric Science Letters. 2012; 13: 108-112.

29. Horlings LG, Marsden TK. Towards the real green revolution? Exploring the conceptual dimensions of a new ecological modernisation of agriculture that could 'feed the world'. Global Environmental Change. 2011; 21: 441-452.

30. Beintema N, Stads GJ. African agricultural R&D in the new millennium progress for some, challenges for many. 2011; 44.

31. ECA. Agricultural Input Business Development in Africa: Opportunities, Issues and Challenges.

32. Denning G, Kabambe P, Sanchez P, Malik A, Flor R, Harawa R, et al. Input subsidies to improve smallholder maize productivity in Malawi: toward an african green revolution. PLoS Biol. 2009; 7: e23.

33. Kyomugisha E. Land tenure and agricultural productivity in Uganda in IFPRI Brief No 5. 2008; 1-3.

34. GFRAS. The "New Extensionist": Roles, Strategies, and Capacities to Strengthen Extension and Advisory Services.

35. AFAAS. African Forum for Agricultural Advisory Services.

36. GFAR. Global Forum on Agricultural Research.

37. CGIAR. CGIAR Research Programs.

38. ADP. African Diaspora Program.

39. AAAPD. Association of African Agricultural Professionals in the Diaspora.

40. Nin-Pratt A, Johnson M, Magalhaes E, You L, Diao X, Chamberlin J. Yield gaps and potential agricultural growth in West and Central Africa. International Food Policy Research Institute. Research Monograph, Washington, 2011; 158.

41. PROMISO. Pearl millet and sorghum yield potential in West Africa.

42. Teklu Y, Tefera H. Genetic improvement in grain yield potential and associated agronomic traits of tef (Eragrostis tef). Euphytica. 2005. 141: 247-254.

43. Oikeh SO, Somado EA, Sahrawat KL, Toure A, Diatta. Rice Yields Enhanced through Integrated Management of Cover Crops and Phosphate Rock in Phosphorus-deficient Ultisols in West Africa. Communications in Soil Science and Plant Analysis, 2008. 39: 2894-2919.

44. Fermont AM, van Asten PJA, Tittonell P, van Wijk MT, Giller KE. Closing the cassava yield gap: An analysis from smallholder farms in East Africa. Field Crops Research. 2009; 112: 24-36.

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