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REVIEW ARTICLE

Capacity Building for Agricultural Biotechnology in Developing Countries

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Abstract:

Introduction:

Agricultural biotechnology holds a unique position in formulating food and trade policies due to its conflicting aspects: its potential to improve food security especially in developing countries, and the intense debates over its risks and unknown impacts on human health and the environment. Agricultural biotechnology, nevertheless, has been widely utilized to help enhance food security with its extensive applications.

Explanation:

The technology is knowledge-resource intensive, therefore reinforcing a gap between developed and developing countries. One of the critical determinants of availability and accessibility of the technology is a developing country's own capacity. Developing countries that wish to benefit the technology should build sufficient capacity. The current study intends to review the concepts of capacity building in agricultural biotechnology, and identify areas frequently considered in need of capacity building; coordinating partnerships, making financial commitment, setting priorities, establishing a regulatory system, and building public awareness.

Conclusion:

While each area has its own territory, they juxtapose on one another to some extends, which can act as a virtuous or vicious cycle to facilitate or obstruct capacity building. Programs for successful capacity building in agricultural biotechnology should consider this nature.

Keywords: Agriculture, Biotechnology, Capacity building, Food security, International development, Nutrition.

1. INTRODUCTION

Population growth and economic inequality are shaping new global demands for food while climate change, volatile energy prices, soil erosion, and water scarcity threaten to make food production more difficult and expensive [1]. According to the United Nations (UN), global agricultural production will need to be at least 60% higher in 2050 than the 2007 level [2]. Simultaneously, agricultural impact on the environment must be reduced [1]. Facing those challenges, many developing countries increasingly find themselves in a more precarious situation to ensure food security. As food security is an evolving multidimensional phenomenon, the World Summit on Food Security articulated it with four pillars: availability of adequate food supplies, access through affordability and entitlement, utilization met with safety and nutritional quality, and stability concerning seasonality and supply disruption [3]. While developing a food system to improve food security represents a global challenge, there seems little consensus as to the best strategies to meet this challenge. In a broader context, some emphasize that poverty should be tackled for hunger and malnutrition, and that the lack of political commitment is a more critical factor for food insecurity than production

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[1]. Others argue that agricultural intensification can achieve sustainable pro-poor growth and that technological innovation appears promising to ameliorate some of the challenges [1, 4]. Of the agricultural tools in technological innovation, biotechnology has been assisting in improving food security despite the intensive debate over its safety and risk, which is not the focus of this study.

For the scope of this study, agricultural biotechnology needs to be defined given the specific definitions it has depending on the context such as inclusion or exclusion of particular techniques. The Convention on Biological Diversity defines biotechnology as 'any technological application that uses biological systems, living organisms, or derivatives thereof, to make or modify products for specific use' [5]. Or, biotechnology refers to an array of techniques useful in agriculture and food; this includes tissue culture and techniques at a molecular biology level ranging from marker-assisted selection, DNA fingerprinting to gene transfer [6]. In the current study, this general concept of agricultural biotechnology is adopted to discuss capacity building in developing countries. The overarching assumption for this discussion is that developing countries would be willing to adopt and utilize appropriate levels of biotechnology to improve food and nutrition security, and achieve agricultural goals.

Advocacy of biotechnology is grounded in that it has a potential to improve living standards in developing countries; its application can increase food production, enhance nutritional quality, improve food safety, and raise health status [7]. However, adoption of agricultural biotechnology implies new investments and changes in resource allocations, responsibilities and market structures. This generally requires intensive knowledge and resources over time, reinforcing a gap between developed and developing countries [8, 9]. One of the critical determinants of availability and accessibility of the technology is a developing country's own capacity [10]. In other words, to capture benefits of biotechnology, developing countries need a qualitative and quantitative transformation of their capacity [11].

Capacity and capacity-building can refer to a specific stakeholder, or in a more abstract manner, for decision-making, policy formulation, human and social capital accumulation, program implementation, or partnerships [10, 12, 13]. Although the actual meanings of the two terms in agricultural biotechnology are context-specific, it is clear that developing countries should build sufficient capacity if they wish to capture proven benefits of the technology for improving food security [14]. Adoption and application of the technology take substantial investment in generating knowledge, resource, collaboration, and political support. Because of this nature, many international donor-led programs include a capacity-building component for the technology transfer to developing countries. There also have been considerable interests in conceptualizing capacity-building and identifying areas that frequently need it. The underlying assumptions of the two tasks are the needs to clarify goals and priorities, and align capacity building with achieving them to better utilize the technology. Thus the objectives of this study are to review relevant concepts of capacity-building and identify common areas frequently in need of capacity building from the perspective of developing countries. This study concludes with positioning agricultural biotechnology capacity in relation to relevant contexts.

2. CONCEPT OF CAPACITY BUILDING IN AGRICULTURAL BIOTECHNOLOGY

Capacity in technical skills, management and decision-making overridingly influences utilization of biotechnology [15]. According to Clark (1995), capacity should be understood within a holistic system of learning and change, where future uncertainties are unknown or unknowable [16]. In scientific research, capacity is identified as 'resources needed to conduct scientific research' or 'the ability of individuals, organizations, and the system not only to perform research, but also to transform research knowledge into successful innovation' [17, 18].

For capacity building, a range of working concepts exist across different sectors and disciplines, each of which intends to better reflect capacity for what to serve to whom [19]. In a broad sense, capacity building can be 'a necessary precondition for the success of major socio-economic development strategies', and it ranges from technical performance, organizational development to institutional empowerment [18, 20]. International development organizations such as the World Bank, Organisation for Economic Cooperation and Development's Development Assistance Committee (OECD/DAC), US Agency for International Development (USAID), and Canadian International Development Agency (CIDA) among others provide general concepts of capacity building in Box **1**.

Conventionally in science and technology, capacity building is understood as 'building up stocks of research infrastructure and trained scientists'. This includes training personnel up to a doctoral level, building and maintaining research facilities, and funding relevant infrastructure [9]. Although building technical skills is part of a capacity building process, sole emphasis on the technical side is questionable. In agriculture, emphasis on technical and physical aspects was rooted in historical patterns of capacity building and concepts of good agricultural practices 40-50 years ago. In the past, it was desirable to create scientifically validated technologies that farmers and others would subsequently use [14]. Currently, agriculture and its practices are understood in a broader socio-political context due to expanding global markets and wider applications of intellectual property. While there is an apparent logic to the view that capacity building in agricultural biotechnology should focus on the technical aspect, contemporary views on knowledge generation and its use suggest this is only part of a larger task of capacity building [14]. Nonetheless, mobilizing efforts to deliver even this technical element becomes challenging to many developing countries with their limited or scarce resources [9]. To better identify capacity building in biotechnology, Hall's work among others' highlighted incorporation of an innovation aspect into capacity building. The central idea of innovation, in a simple manner, is to put the produced knowledge into use [14]. In agricultural biotechnology, it implies capacity building is to enhance the ability not only to produce technical skills, research materials and knowledge, but also put them into agricultural practicality so as to improve food and nutrition security and achieve agricultural goals.

Box 1. Concepts of capacity building from the select international development organizations.

World Bank: Locally driven process of learning by leaders, coalitions and other agents that brings about changes in socio-political, policy-related, and organizational factors to enhance local ownership for and the effectiveness and efficiency of efforts to achieve a development goal [21]
OECD/DAC: Process of unleashing, strengthening and maintaining the ability of people, organizations and society as a whole to manage their affairs successfully [22]
USAID: Process of change in which people, organizations, and societies can improve their performance over time [23]
CIDA: Approaches, strategies and methodologies used by a developing country and external stakeholders to improve performance at the individual, organizational sector or broader system level [19]

A different approach to look at capacity building may be to examine capacity deficit. Wubneh (2003) discussed causes of capacity deficiency in agricultural biotechnology in Africa: (1) institutional failure to adapt to a changing social, economic and technological environment, (2) convergence of political and economic crises, (3) decline in education, and (4) dependence on external assistance. This reconfirms that all aspects of a society influence capacity and capacity building [11]. However, capacity building should not be assumed to start at zero; capacity in individuals and institutions, weak as it may be, does exist [9]. Donor agencies often fail to recognize existing capacity as a starting point for capacity building, or to consider any level of capacity that existed in the past [13]. It is generally difficult to gather empirical evidence for examining a level of existing capacity [9]. Accordingly, a chance to accumulate capacity on the current level may be lost without conducting a capacity assessment designed in a context-specific manner.

In short, capacity building in agricultural biotechnology has its specific and focused meaning. The following therefore is a suggested synthesized concept; a process of enhancing existing abilities to improve technical skills, generate knowledge and supportive institutions, and utilize the outcomes in agriculturally practical and socially viable ways for improved food and nutrition security.

While conceptualization of capacity building makes it and its need better understood, identification of the areas that require capacity building helps achieve goals and priorities by effectively employing the technology. To identify frequently-mentioned areas for capacity building, eight peer-reviewed papers were selected that specifically focused on capacity building for agricultural biotechnology in developing countries. The limited availability of the literature for this discussion may reflect the need for further attention to capacity building for agricultural biotechnology in developing countries. The fact that even these papers published some years back are still very relevant implies inadequately improved agricultural capacity over time.

3. AREAS FREQUENTLY MENTIONED FOR CAPACITY BUILDING IN AGRICULTURAL BIOTECHNOLOGY

Five areas are identified that commonly require capacity building in developing countries to utilize agricultural biotechnology. Those areas are coordinating partnerships, making financial commitment, setting priorities, establishing regulatory systems and building public awareness of the technology (Table **1**). Following the Table, each area is discussed in detail.

Table 1. Five areas that were commonly identified across the reviewed papers for capacity building in agricultural biotechnology in developing countries.

Areas	Number Mentioned and Reference in Superscript	Note on Areas
Coordinating partnerships	7 [24 - 27, 14, 8]	Other terms such as aligned partnerships, coordinated alliances and linkages seemed interchangeable with coordinated partnership.

(Table 1) contd.....

Areas	Number Mentioned and Reference in Superscript	Note on Areas
Financial commitment	6 [8, 9, 24, 27]	Funding is allocated or committed to adopt, utilize or control agricultural biotechnology.
Priority setting	5 [9, 24 - 27]	Priorities and agendas are set for agricultural research and development.
Regulatory system	5 [25], [8], [26], [14], [28]	Regulatory systems are to control biotechnology adoption, utilization, safety and risk assessment, and market trades etc.
Public awareness	4 [8, 25, 28, 27]	The public need be sufficiently aware of the technology through fair and transparent channels.

3.1. Coordinating Partnerships Among Stakeholders, Especially Between Public and Private Sector

Coordinating partnerships among stakeholders is one of the frequently mentioned areas in the reviewed papers for capacity building. Terms the papers used were slightly different such as aligned partnerships or coordinated alliances, yet appeared interchangeable. The importance of coordinated partnerships comes from the fact that stakeholders collectively provide creative thinking and innovative options and generate synergies. Also, coordinated partnerships incorporate various interests and values, and effectively question power dynamics [29]. Nevertheless, difficulties arise when building and sustaining partnerships because stakeholders' participation changes with economic and political agendas. Furthermore, levels of stakeholders' endowment of accessible information and resources discriminate their participation in partnership as it may disproportionately favor particular stakeholders [29]. Starting from an end-user of the technology, Machuka (2001) emphasized engagement of farmers and farmer organizations in decision-making and partnership. This bottom-up approach can encourage farmers' full involvement for solutions suited to a local agro-ecology and socioeconomic system, not short-term quick-fix solutions [25, 30]. Yet, the reviewed papers focused more on public-private partnerships due to the nature of agricultural biotechnology; commercialization of research outcomes and their marketing, distribution and trade.

Generally, the public sector that includes government agencies, public institutions, and universities is an initial driving force for biotechnology because of necessary upfront investment and lack of economic incentives for private participation. The public investment in the technology is justified by that the outcomes have characteristics of public goods i.e. contributing to social benefits and welfare [31]. The agricultural research intensity, or ARI, is a commonly used indicator to assess national agricultural research efforts. ARI is an expression of national expenditure on public agricultural research and development as a share of agricultural gross domestic product or GDP [32]. Since the 1960s, developing countries have made little improvement with ARIs although agriculture accounts for a large share of their overall economy [32]. In addition to the insufficient national efforts, increasingly restrictive ownership of knowledge and materials changes patterns of partnerships driven by profits, and entails high costs for the public sector to deliver its research outcomes for public good. This trend disadvantages the public sector in developing countries to move biotechnology programs forward on their own [14].

The Article 22 of the Cartagena Protocol on Biosafety recognizes the essential role of the private sector in creating and strengthening developing countries' capacity; effective implementation of the Protocol requires facilitated private sector involvement [33]. The public-private partnership differs from a one-direction technology transfer in that the two sectors mutually benefit [9]. Through the partnership, the private sector gains access to local potential markets, regulatory or financial incentives from the government, and may enhance public relations from its involvement. The public sector, on the other hand, earns systemic marketing and management skills, additional capital, and advanced knowledge [31]. Most importantly, the private sector involvement can facilitate commercialization of the public or joint research outcomes. The private sector tends to better read market signals than the public sector with limited know-hows in commercialization. Arrangements with venture capital, cooperative projects or more likely on a contract-basis can be a feasible way to engage the private sector in partnership [33].

In developing countries, disincentives exist for private participation such as high costs of serving resource-poor farmers who are often remotely located, difficulty in protecting intellectual property rights (IPRs), unpredictable regulatory systems, and immature value chains for agricultural products [32]. While the two sectors should cooperate to define common goals, identify each other's complementary assets, and analyze market potentials, they need to acknowledge fundamental differences in their operational values and cultures. The public sector intends to maximize social benefits mostly by targeting resource-poor farmers whereas the private sector operates for financial benefits. Thus, the two should negotiate to avoid impinging on each other's market segment or creating monopoly once the private sector is well established after the public support at the early stages of the private sector involvement [26].

Besides the public-private partnership, it may be essential to establish geographic alliances among public institutions across neighboring countries that have different comparative advantages in research and development, and resource endowments under similar agro-ecological conditions. A regional partnership allows for public institutions in developing countries to gain bargaining power and available resources, cross-license one another, share the costs, and increase the size of a potential market [26, 31]. It also raises a political voice of the region and in some cases helps compete with the private sector. Yet, spreading limited resources across too many regional partners may increase coordination costs and fail to sustain their involvement [34].

The reviewed papers mostly emphasized the public-private partnership due to the nature of agricultural biotechnology, participation of farmers and consumers as the technology end-users must be ensured. Without their active participation in decision-making, outcomes of the technology could be little relevant to urgent production concerns, and increase public skepticism in the safety of outcomes.

3.2. Making Financial Commitment to Agricultural Biotechnology

Resources available for agricultural investment are one of the indicators of the efforts to strengthen capacity [8]. Likewise, effective mobilization of capable personnel, supportive infrastructure, and favorable market conditions facilitate development and utilization of the technology. This requires long-term political commitment with ensured budgetary sources especially when other financial means are limited in developing countries [8, 32].

Governments need to allocate sufficient and predictable budget in order to tap global advances in agricultural biotechnology for improved food security [26]. One challenge in doing so is to balance funds between basic and applied research, and between programs tied and untied to political agendas [32]. Another challenge is to manage a funding mechanism that is flexible without heavy bureaucracy. Complex and inflexible funding mechanisms prevent stakeholders from swiftly responding to market trends and needs [35]. At the same time, responsible government agencies must transparently manage public funds to earn public trust for sustained supports of the technology [25].

While heavy dependency on international donors or limited national funding may reduce national will to assign funds to biotechnology [9], collaboration with the private sector can identify a new venue for additional capital such as commercializing research outcomes. Their commercialization allows for the public sector to capitalize its investment, further improve research facilities, and incentivize highly skilled staffs in order to retain them [33]. This comes back to establishing strategic partnerships between the two sectors.

3.3. Setting Priorities for Research Agendas and Agricultural Goals

It is necessary to set clear priorities and strategies for agricultural biotechnology to target the most needed for food security and other agricultural goals [8]. When research agendas reflect national priorities, massive support can be more easily gathered [9]. For this reason, many agricultural research organizations have instituted formal priority-setting mechanisms, often with donor support, to ensure national goals and needs are consistent with their resource allocation [36].

Applicability of agricultural biotechnology is different based on farming practices, agro-ecological conditions, socioeconomic status of users and trade regulations. These factors determine to what extent the users would take up the biotechnology, yet complicate setting research priorities and agendas. Priorities and agendas may be established with two approaches; a supply-oriented or demand-oriented approach [36]. The supply-oriented approach largely sets priorities within a hierarchical research system as in top-down. The demand-oriented approach sets them based on user perspectives, and employs consultative and participatory methods. If implemented at the priority-setting stage, the demand-oriented approach can select more suited types of the technology, and better capture different needs of user groups [4, 36].

Many research agencies in developing countries established biotechnology programs without defining clear priorities even under complex market and trade conditions. Part of the reason is that adequate capacity was unavailable to assess the needs and determine the priorities [37]. Additionally, it is difficult to integrate research priorities both pro-poor and pro-market because they often conflict with one another, and require initial consensus between the public and private sector [26, 38].

3.4. Establishing Regulatory Systems for Agricultural Biotechnology

Political climates strongly influence the ability of stakeholders to express their capacity [39]. Instead, policy makers as a stakeholder can set the tone of political climates through a regulatory system around agricultural biotechnology. A regulatory system thus can be a good proxy to gauge a political tone for the technology. In line with this, Byerlee (2002) and Hall (2005) stressed investment in regulatory systems [8, 14].

The public and private sectors engaged in agricultural biotechnology are directly subject to relevant regulations. They are influenced by and adapt to how the regulatory system functions. The two sectors operate more effectively under a regulatory system that is sensible and consistent as it deeply affects the technology outcomes, their marketing, trade and usage [8]. Transparency of the system is equally critical to ensure the perceived independence and objectivity of the decision-making process [15]. Yet, it is mostly the responsible government agencies that set, run and modify a regulatory system in the local, national, and international contexts [8]. In this regard, a national government can act as a system builder and facilitator to determine a level of technology uptake and utilization. As preference of biotechnology products varies across developing countries, individual countries should establish a customized regulatory system that meets their own needs and goals [9, 29].

A supportive regulatory system around biotechnology allows its efficient use with favorable biosafety and IPRs policies [14]. In particular, the value of IPRs tends to be less appreciated across developing countries because of their limited investment in biotechnology itself, underdeveloped IPR regulatory protocols and low private sector participation. For effective IPRs, a government has to define a protection level of biotechnology outcomes, set regulations that conform to international IPR provisions, and determine cost effectiveness of the granted protection to the inventors and end-users of the protected outcomes [29]. While it is essential to set a regulatory system customized to the needs and values of an individual country, a regional coordination of the individual systems is as essential to create synergies for improved regional food security. A major challenge is the current regulatory heterogeneity on biotechnology and its outcomes. Due to a variety of political stances on biotechnology, approval of a new biotechnology product does not occur simultaneously across trade partners and their regulatory systems [40].

For developing countries that depend on international trade for agricultural products, changes in external environments are a significant consideration for their regulatory system. Presently, one of the external factors that influence biotechnology adoption is the mixed signal on agricultural biotechnology that the United States and European Union send to markets. The American policy stance on biotechnology emphasizes product similarities between the conventional and biotechnical, or transgenic breeding. This approach is based on the principle of substantial equivalence, in which transgenic products are viewed as comparable to the products of conventional breeding. On the other hand, European skepticism on biotechnology products arises from the precautionary principle in which they are viewed as fundamentally different from conventional breeding [41]. This mixed signal often acts as an important variable in developing countries where the two powers probably set the rules for food aid programs as well as agricultural trade.

In short, a sound regulatory system for agricultural biotechnology should be flexible in decision-making and prompt in improving regulations. It should also disseminate timely information and allocate appropriate responsibilities among stakeholders [8]. Simple presence of a sound regulatory system does not guarantee much unless capacity to operationalize the system is built hand-in-hand. Therefore, capacity building needs to be emphasized with setting a regulatory system.

3.5. Building Public Awareness About Agricultural Biotechnology

Science in general, and biotechnology in particular, has hardly evolved in a socio-political vacuum since the public tend to determine the fate of a technology and its outcomes with their acceptance or rejection [8, 33]. Public confidence thus decides the extent to which its society may adopt and further invest in the technology. Accordingly, public perception of the risk-benefit influences the direction of technological innovation, and is influenced by information from industry, government, scientists, interest groups, and media [33]. For this reason, it is critical to assess the validity of provided information based on science, social values and uncertainties attached to the outcomes, and policy options to manage the uncertainties [29]. While regulatory agencies are expected to provide the public with factual information on biotechnology products, competence of those agencies in many developing countries is often questioned. Furthermore, passive political reactions to intensifying debates on biotechnology products may cause public skepticism on the technology itself and the responsible authorities.

Other obstacles exist against information sharing with the public. Ineffective or inexistent science education in developing countries prevents the public from keeping pace with advancing biotechnology and its benefit and risk [33]. Moreover, how to frame the dialogue influences public perception of the technology, as false information creates conflicting claims and confuses the public. In this regard, the Article 23 of Cartagena Protocol promotes public awareness through educational campaigns for the safe transfer, handling, and use of the technology [42]. In particular, educating a specific user-group such as farmers and consumers helps strengthen their confidence and knowledge to participate in the decision-making process [29].

Roles the media assume are increasingly visible in biotechnology, and their impacts are well documented. In part, power in policy-making revolves around the ability to control media attention to an issue and frame the issue in favorable terms [43]. These two characteristics of media coverage both reflect and shape how the issue is decided, by whom and with what outcomes [43]. For instance, Golden Rice, a transgenic rice variety with enhanced pro-vitamin A to help alleviate vitamin A deficiency in developing countries, has both benefitted and suffered from media coverage. Also, the media has partly influenced the rice's current regulatory status, a regulatory limbo [44]. For as sensitive an issue as agricultural biotechnology, the media can sway the direction of public perception with unsubstantiated advocate, neutral and fair coverage or sensationalized disapproval.

If safe application of agricultural biotechnology is to improve food security in developing countries, the technology should coevolve with the public consensus on the technology in the social, political, cultural and economic terms. Therefore, informing the public of all aspects of the technology is essential for a mutual understanding of its benefit, risk, cost, and policy direction. Yet, implementing awareness campaigns require funds with policy support, and the campaigns need wide collaboration for information dissemination logistics. All activities are only possible with stakeholders whose capacity is sufficiently built to implement them [29].

CONCLUSION

The limited availability of the literature for this discussion may reflect the need for further attention to capacity building for agricultural biotechnology in developing countries. The fact that even these papers published some years back are still very relevant implies inadequately improved capacity over time. The question with agricultural biotechnology now is becoming less about the creation of appropriate pro-poor technology for developing countries, but more about the creation of a viable system to effectively meet the needs for improved food and nutrition security.

To emphasize the significance of capacity for agricultural biotechnology, it is positioned in relation to the relevant contexts within a system (Fig. **1**). This system assumes that the macro-political and economic conditions, donor dynamics and other uncontrollable factors affect the development and expression of capacity, and that capacity plays out to influence the sub-contexts within the system. Although simplified, this visualization shows sufficient capacity is required to build a sound regulatory system. This in turn fosters social and financial benefits separately to assist in achieving food and nutrition security.

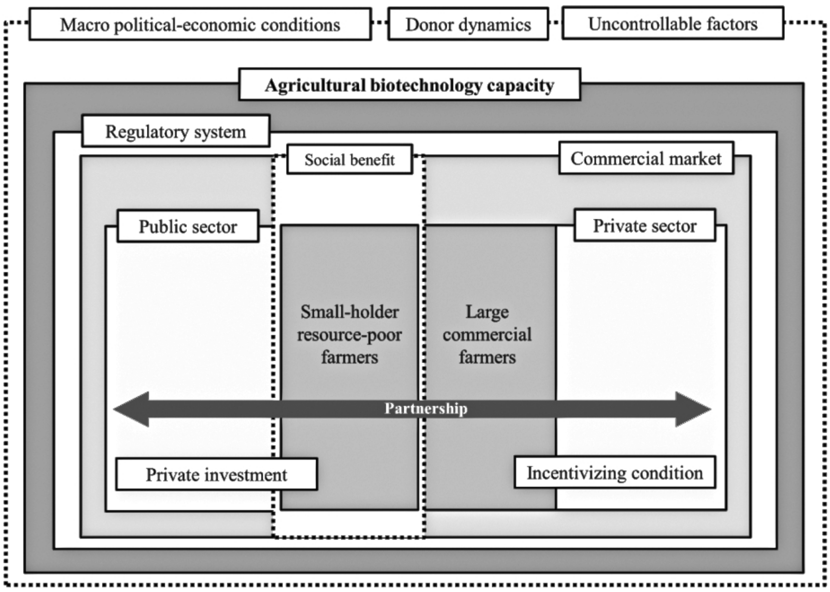

Fig. (1). Visualization of capacity building for agricultural biotechnology in relation to the relevant contexts.

Capacity building implies costs that must be weighed against expected benefits, and relies upon various strategies that include strengthening existing capacity and making better use of it [8, 19]. Programs for capacity building should be preconditioned with legitimate policies and strategies, easy access to means and available resources for implementing them, and public support [19]. Ironically, to meet these preconditions, sufficient capacity is needed. Theoretically, developing countries should take initiatives to drive the process of capacity building, but again taking initiatives entails adequate levels of pre-existing capacity. This situation creates either a virtuous up cycle or vicious down cycle to take up the technology. Nevertheless, capacity, if sufficiently built, increases power, confidence, motivation, and accountability in stakeholders to achieve food and nutrition security, and agricultural goals.

Agricultural biotechnology holds a unique position in domestic and international food policy formulation. It is a particularly sensitive issue because of its direct relationship with food, human health, and the environment. Another contributing factor to the issue's sensitivity is the rapid advancement of the technology over a short period of time without sufficient lead time for building public confidence in the safety of outcomes. However, biotechnology has helped improve food situations by enhancing the four pillars of food security. For instance, the technology has facilitated the availability side by increasing productivity with pest resistance in crops and the utilization side with micro-nutrients biofortification.

Many developing countries that wish to benefit from the safe use of the technology lack capacity, not just for the technical skills but institutional ones. Production of technical outcomes does not guarantee success in achieving agricultural goals without practical utilization. This study reviewed capacity building in agricultural biotechnology, and discussed the five areas in need of capacity building. These areas are inextricably interconnected and interacting. Without a coordinated partnership among key line-ministries and relevant stakeholders from the public and private sectors, setting a sound regulatory system and allocating national grants will be unsuccessful. Also, without such a regulatory system, markets will not function, and safe adoption and utilization of the technology cannot be ensured. This increases the public skepticism concerning the technology and its outcomes. Given those issues, strengthening each area is important. Yet collective progress of these areas is more important for developing countries to exploit their limited resources. Donors need to make long-term commitments to assist developing countries in capacity building given that the benefits of the technology accrue over a long period of time. However, making such a commitment is difficult when success of donor programs tends to be measured based on short- to medium-term results [45].

For further studies with capacity building in general, challenging research areas may include how to monitor and evaluate capacity being built during what period of time, with what indicators, and how to sustain the enhanced capacity under constantly changing contexts. In agricultural biotechnology, these tasks are also burdened with the fast evolution of the technology itself and increasing public interest in food and the environment.

CONSENT FOR PUBLICATION

Not applicable.

CONFLICT OF INTEREST

The author declares no conflict of interest, financial or otherwise.

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