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Chapter 2

INTERNATIONAL RESEARCH COLLABORATION IN AGRICULTURE

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ABSTRACT

Globalization in science and innovation is progressing rapidly. Addressing the growing complexity of evolving challenges such as climate change, animal and human health issues, food security and biosecurity within a globalised context will require the application of past experience from international collaborative research. Developing nations are now expected to establish programs for improving agricultural productivity while supporting international research initiatives, provide further support for existing ones, and improve their global engagement in agricultural research and education. This chapter aims to outline key strategies for developing international collaborations towards sustainable development of agricultural systems.

Emerging economies, particularly in pan-Asia, and pan-Africa are increasingly attracting global networks for new international collaborations. This chapter highlights the nature of international collaborations and outlines key agencies that may provide funding for collaborative research. Following a summary of global and national level benefits, we provide underpinning key drivers for international collaboration at the global, national, institutional and researcher level. Policy, human resource, and infrastructure development are discussed as key strategies for enhancing international collaborations. The application of outlined strategies seeks to assist, improve, and expand international research collaborations, particularly in developing countries with large agrarian populations, with the aim of forwarding sustainable development in agriculture.

Keywords: Agriculture, international collaboration, developing countries, Africa, sustainable development, research collaboration

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1. EVOLVING INTERNATIONAL AGRICULTURAL COLLABORATION

In the 21st century's globalised world, it is more important than ever to be engaged in successful and productive collaborative international research (Altbach & Knight, 2007; Glew, 2008). Issues once perceived as regional problems have become truly international, such as health, security, biosecurity, food and energy security, sustainable population growth and agricultural development. An international approach requires a collaborative commitment of interdisciplinary researchers from around the globe, who are well supported by their governments. Developed countries have world-class infrastructure, including cutting-edge technologies and research expertise in many fields of science. This strong starting point positions these countries well to engage with the wider international community in both developed and developing nations.

Science at the international level is now a complex adaptive system comprised of hundreds of international agents (Leydesdorff & Wagner, 2008), and larger integrated multi-disciplinary teams are becoming increasingly necessary to tackle modern scientific questions (Glover et al., 2008). Due to food security problems, particularly in less developed countries, there is an ever increasing need for improving agricultural productivity. Despite the availability of modern farming inputs in less developed countries (such as fertilizers), due to the lack of access to much knowledge, expertise, and technology, a considerable yield gap still exists between the developing and developed countries. Therefore, there is a greater need for internationally collaborative projects for knowledge and technology transfer to developing countries for sustainable agricultural development.

In parallel with research, the internationalization of higher education has led to institutions from developed countries establishing international branches (Altbach & Knight, 2007). As such, there is a growing nexus between international collaborative research and higher education (Dolby & Rahman, 2008). In a knowledge-intensive society effective research and education institutions are essential for generating social and economic progress (Mohrman et al., 2008). Nonetheless, embarking on international education and research collaborations is a long term and expensive investment, and is often associated with national socio-political objectives (Kerwin, 1981; Glew, 2008). Hatakenaka (2008) reviewed international research collaborations and partnerships between various institutions and countries. She stated that the UK Department for International Development (DFID) was one of the first official donors to identify the need for research and development through international collaborations. Subsequent joint collaborative ventures between the UK and particularly US higher institutions have been established. Further, UK DFID established the Education Quality in Low-Income Countries (EdQual) program for capacity building and promoting research leadership in Sub-Saharan African Institutions (Barrett et al., 2011). Similarly, Australia has established bilateral research agreements with China and India in recent years to enable scientists to undertake joint projects. Japan has also invested in building international linkages since the early 1980s in order to attract international students to Japan and to promote international research collaborations within targeted programs, i.e. Swedish Karolinska Institute. Likewise, US universities have a long established record of attracting top students from around the world to not only supplement the 'brain power' needed for new technologies and innovations, but also to establish a capable workforce for global competitiveness.

Globally, research and development (R&D) investment has increased by 45% since 2002 (The Royal Society, 2011). While countries such as India, Iran and Brazil have increased their R&D budgets substantially and subsequently had up to 12% annual growth in publication output over the the period of 1998 and 2008, their growth in internationally collaborative research papers has lagged behind (The Royal Society, 2011). This suggests that these countries have not improved their internationally collaborative research projects at the same rate as their investments. The Royal Society (2011) stated that developed countries such as the US, UK, Germany, Japan, and France have published the vast majority of research papers in the last 10 years. For some time it has been known that specialized and established areas of research exhibit lower international co-authorship and collaboration than emerging fields of endeavor (Davidson & Carpenter, 1979). Therefore, those left outside the growing core of dominant research-intensive nations may become disadvantaged by declining collaborative opportunities and loss of major new knowledge and technological benefits (Leydesdorff & Wagner, 2008). Furthermore, The Royal Society report emphasized that more effort is needed to build international engagements and collaborations between the developed world and developing countries (The Royal Society, 2011). This paper aims to contribute a personal perspective and provide novel ideas to policy makers and scientists on how to improve and expand international research collaborations, particularly in developing countries by describing the benefits, impediments, key drivers, and strategies.

2. THE NATURE OF INTERNATIONAL RESEARCH COLLABORATIONS

An international research collaboration occurs in various forms and for various reasons (Glew, 2008; Jonkers & Tijssen, 2008; Chinchilla-Rodríguez et al., 2010). In general, each funding agency has a specific goal for funding an international project, and the source of available funds generally characterizes the nature of an international collaboration (Kerwin, 1981; Glew, 2008). A selected list of agencies and programs enabling international collaborations through direct funding are listed in Table 1. Detailed information regarding these agencies can be found on their respective web sites. The nature of international research collaborations falls into several categories:

- Collaborations where each international partner contributes cash to a joint research project. Partners also provide in-kind contributions, i.e. infrastructure and personnel. This type of collaboration requires material transfer agreements (MTA) and/or contracts for bilateral agreements such as a Memorandum of Understanding (MOU), and always leads to tangible outputs such as a product and/or a research publication that benefit all research partners.
- Collaborations, often without financial contributions, where goodwill and established professional relationships between researchers enable information and material exchange, and where small experiments are conducted towards a common goal. These arrangements, generally without a contract, often provide valuable information for both partners with at least a joint publication being the end result.

- Collaborations driven by international organizations such as Food and Agriculture Organization (FAO), World Bank, and development agencies such as Rockefeller, GATES, The Kirkhouse Trust, Clinton Foundation. These collaborations, requiring block funding, usually aim to solve a particular regional or global problem over a period of time, and are driven by a group of researchers with common interests. Each partner may also contribute their own resources as in-kind contribution. Generation Challenge Programs (GCP), the Basic Research to Enable Agricultural Development (BREAD) program, and the Borlaug Global Rust Initiative (BGRI) are some examples of this kind of alliance in agricultural sciences. For illustrative purposes, the BGRI is a wheat rust research collaborative network comprising at least 16 countries. The initiative primarily focuses on Sub-Saharan Africa to prevent further rapid rust pathogen mutation and movement into other vulnerable populous regions such as Asia (McIntosh & Pretorius, 2011).
- Collaborations driven by specific government funding towards certain parts of the world. Recent programs involving Australia targeting East Africa and South East Asia, UK DFID programs targeting African higher education institutes, a block funding from the Mexican Government through International Maize and Wheat Improvement Center (CIMMYT), or USAID funds targeting certain parts of the world are some examples. Funding by the National Institutes of Health (NIH) towards fostering relationships between American Scientists and scientists from African countries for finding a cure for Human immunodeficiency virus (HIV) is another good example.
- Collaborations driven by regional or continental organizations those aim to improve the well-being of people in those particular regions. Examples include: European Union framework research funding programs (Framework 7, Marie Curie Actions), the Consejo Nacional de Ciencia y Tecnologia (CONACYT) in Central America and South America, and a more recent initiative that is still under development— Association for Strengthening Agricultural Research in Eastern and Central Africa (ASARECA).
- Collaborations driven by private-public partnerships on key research and innovation areas. Collaborations may also be driven by private investment groups towards product development or promotion of a product or service. A universal need for action on climate change and dealing with infectious human and plant diseases also lead to new private-public partnerships to support research and innovation in both developed and developing countries. Funding from the Heineken Corporation towards developing drugs for HIV patients in Africa is a good example of this type of collaboration. A more recent partnership between the Bill and Melinda Gates Foundation and the National Science Foundation of USA funded the BREAD program, enabling researchers to use new approaches and technologies to tackle problems faced by small farms in the developing world, particularly Africa.

Table 1. Selected list of funding agencies and web addresses

Funding agency	Web site
Australian Centre for International Agricultural Research (ACIAR)	http://aciarc.gov.au/
Australian Government Overseas Aid Program (AusAid)	http://www.ausaid.gov.au/
Bill and Melinda GATES Foundation	http://www.gatesfoundation.org/
Clinton Foundation	http://www.clintonfoundation.org/
EU Marie Curie Actions	http://ec.europa.eu/research/fp6/mariecurie-actions/action/fellow_en.html
European Cooperation in Science and Technology (COST)	http://www.cost.esf.org/about_cost
European Union Framework Seventh (EU F7)	http://cordis.europa.eu/home_en.html
Food and Agriculture Organization (FAO)	http://www.fao.org/
Fulbright Scholar Program	http://www.cies.org/about_fulb.htm
International Atomic Energy Agency (IAEA)	http://www.iaea.org/
International Centre for Genetic Engineering and Biotechnology (ICGEB)	http://www.icgeb.org/home.html
International Foundation for Science (IFS)	HTTP://WWW.IFS.SE/
National Institutes of Health (NIH)	http://www.nih.gov/
National Science Foundation (NSF)	http://www.nsf.gov/
Rockefeller Foundation	http://www.rockefellerfoundation.org/
The Consejo Nacional de Ciencia y Tecnología (CONACYT)	http://www.conacyt.gob.mx/
The Crawford Fund	http://www.crawfordfund.org/
The Human Frontier Science Program (HFSP)	http://www.nhmrc.gov.au/grants/apply/strategic/hfsp.htm
The Kirkhouse Trust	http://www.kirkhoustrust.org/
The Wenner-Gren Foundation	http://www.wennergren.org/
United Kingdom Department for International Development (DFID)	http://www.dfid.gov.uk/About-DFID
United States Agency for International Development (USAID)	http://www.usaid.gov/
World Bank	http://www.worldbank.org/

3. BENEFITS FROM ENGAGING IN INTERNATIONAL COLLABORATIONS

Benefits from participation in international research collaborations differ at global, national and regional levels, and also at the institution and researcher levels. International recognition through joint publications is the most common benefit to researchers. Collaborations involving complementary skills and technologies allow researchers to conduct and address more complex research questions in a more cost-effective way. Further, international collaborations provide opportunities for researchers to travel to new places, meet

new people from different cultures, and hence broaden their horizons (Ynalvez & Shrum, 2010).

For economic reasons and in order to access new student markets, allowing researchers to access research students, a growing number of universities are establishing campuses in other countries (Altbach & Knight, 2007). These engagements aim to enhance international recognition of these universities. Collaborative research output is often enhanced by cultural and intellectual familiarity (Traoré & Landry, 1997). Collaborative research platforms based on geographically proximal institutions and researchers with parallel socio-economic and industrial interests reflects a historical experience of past successful approaches (Ponds et al., 2007; Cooke, 2009; Chinchilla-Rodríguez et al., 2010). Such strategic geographical ‘clustering’ approaches require prioritization of specialization and also structural encouragement (Birch, 2006; Rural Research and Development Council, 2011). Geographical clustering is likely to enhance professional networks, which is more strongly related to publication productivity than other forms of collaborative activity (Ynalvez & Shrum, 2010). The plethora of factors influencing the success (or otherwise) of international collaborations can be examined at the various structural levels.

3.1. Global Level

In agriculture, for example, international research collaborations can play a role in alleviating poverty by providing food security in developing countries. Such research activities have long-term positive spin-offs for countries at all levels of development, in both security and economic terms. Key global benefits include:

- effective use of global research and development funds and expertise to solve common research problems
- global knowledge and technology sharing
- ensure developing countries build sufficient human resources and research and development capacity
- alleviate poverty in Africa and South Asia for better population dynamics/reduced human movement around the world
- transnational research approach to solving common problems
- improve regional and global peace and prosperity.

3.2. National Level

More far-sightedness and creative thinking for the long-term benefits to each country will yield more social and economic returns, for example improving regional and global peace and prosperity. Key national benefits include:

- enhance each country’s international research reputation
- access to international knowledge and expertise
- access to international infrastructure and technology

- enable each country to compare its research quality and expertise with that of other nations
- stimulating environment which triggers new ideas, technologies and innovations
- social and economic benefits to each country
- engender greater understanding of causes and impacts of development in developing nations.

Table 2. Key drivers of international research collaboration at global, national, institutional and researcher level

Global	National	Institutional	Researcher
<ul style="list-style-type: none"> • Global food and energy security • Global knowledge economy • Secure and promote local R&D in each country • Emerging opportunities and prosperity in China and India • Global human health • Global plant and animal health • Global awareness of African and south Asian poverty and living conditions • Cost of solving global research problems • Global spread of key expertise in one research area • Biosecurity issues requiring global cooperation • One world, one nation philosophy 	<ul style="list-style-type: none"> • Gain international reputation • Access to emerging markets • Develop internationally-competitive industries • Ensure national food/energy security • Ensure international food/energy security • Ensure science and innovation benefits own people • Infrastructure and cutting edge technology access • Humanitarian reasons • Establish global networks to educate future scientists • Understand science drives economic development • Improve domestic-international relations 	<ul style="list-style-type: none"> • Build reputation • Attract international students • Access to world class facilities • Attract additional government funding • Attract international research funding • Create self-sustainable income through innovations and discoveries • Benefit from student and staff exchanges 	<ul style="list-style-type: none"> • Develop transnational research projects that are highly rewarding professionally, intellectually and culturally • Build increased reputation from joint publications with international researchers • Access to knowledge and infrastructure • Gain personal satisfaction from global impact • Gain international mobility • Access international students and research projects • Collaborate with the world's 'best and the brightest'

4. KEY DRIVERS OF INTERNATIONAL RESEARCH COLLABORATIONS

International collaborations are global phenomena that can be driven at multiple levels from national and regional governments to institutions and individual researchers (Table 2). Each level has a key role to play in the development of a global perspective for research collaborations. The key driver at every level is to make collaborations more prosperous, productive and internationally competitive. The availability of key research staff with global

views and appropriate communication skills is vital for productive and constructive international research collaborations (McColl-Kennedy, 2008).

Building reputation and track-record to attract good scientists and more funding for research and teaching are key drivers at the institution level. For example in Australia, recent government funding schemes have taken each university's student loads and publication records as the main criteria for determining funding. Coupled with the need to attract more international students, most universities are proactive in staffing/head-hunting scientists with better track-records in order to build better international relationships.

5. IMPEDIMENTS TO INTERNATIONAL COLLABORATIONS

International research collaboration can be complex and effective strategies are needed for proper management (Bagshaw et al., 2007). In particular, legal and regulatory issues which may hamper project progress need to be discussed and agreed upon at the beginning of an international collaboration. Some regulatory issues were extensively discussed in a 'Collaborative Leadership Development Series Workshop' at the University of Minnesota in April, 2010. Anderson and Steneck (2010) further highlighted cultural and linguistic differences, differences among national research systems, differences in legal and governance, and lack of infrastructure in developing countries as some of the barriers when establishing international research collaborations. One of the major hindrances to meaningful collaboration is the educational philosophy in countries such as India and China where rote learning and hierarchical teaching structures inhibits innovation (Turner, 2009). Researchers in non-English speaking countries may find it difficult at international meetings due to lack of language proficiency even though they conduct cutting-edge research. Lack of funding or support for face-to-face meetings can also limit the establishment of international research projects. Some impediments faced at global, national and institutional levels are listed below.

5.1. Global Level

- insufficient funds for global initiatives
- governmental regulations
- international visa requirements and speed of visa approvals
- competition and legal issues for global intellectual property rights
- unstable political systems in less-developed countries
- lack of managers with global vision to initiate and drive collaborations.

5.2. National and Institutional Level

- tyranny of distance—the need for face-to-face meetings, to commence and sustain a collaboration, but they can be expensive, both financially and time-wise
- lack of emphasis on the need for international research experience during postgraduate training

- lack of funding for international students
- insufficient infrastructure to support for commercialization and to manage intellectual property issues
- inter-institutional competition within each country for available resources for international research engagements
- insufficient support and encouragement to attend and/or organize international conferences
- lack of discretionary funds and spending flexibility in existing research funding
- issues with bilateral agreements between nations.

6. STRATEGIES ENHANCING INTERNATIONAL RESEARCH COLLABORATIONS

Strategies can be implemented at the global, national, regional, institutional and individual researcher level (Table 3). Creation of mutually beneficial outcomes between developed and developing countries or among countries and researchers in general ought to be the main aim of collaboration. This will ensure maximum participation in collaborative engagements. Strategies that could be implemented at various levels are described below.

Table 3. Strategies at various levels to enhance international research collaboration

Level	Strategies
Global	<ul style="list-style-type: none"> • Promote international information exchange • Establish problem-based transnational research teams • Capacity building in developing countries
National	<ul style="list-style-type: none"> • Develop national policies to stimulate international research collaborations • Develop human resources • Develop infrastructure
Institute	<ul style="list-style-type: none"> • Establish bilateral agreements • Become internationally focused • Develop systems to support researchers with international capacity
Researcher	<ul style="list-style-type: none"> • New initiatives • Publications • Engage with other scientists through international meetings and conferences

6.1. Global Level

6.1.1. Promote International Information Exchange

International development agencies (FAO, World Bank, etc.) need to ensure that first-rate international meetings and conferences are well-supported and strategies established to ensure

maximum information dissemination. Establishing grants and programs that encourage scientists to join and/or organize high caliber international associations and conferences must be a top priority. Widespread participation in such activities can have positive impacts for the entire global research community.

6.1.2. Establish Problem-Based Transnational Research Teams

Establishment of transnational research teams for common problems (i.e. Borlaug Global Rust Initiative, International wheat and barley genome sequencing consortia) would allow international expertise in one particular field to work together. This would enable more effective use of international research funds for common goals. FAO, World Bank, international development agencies and governmental agencies ought to actively encourage the formation of such collaborative transnational research teams by providing funds.

6.1.3. Capacity Building in Developing Countries

Encouragement of collaborations between developed and developing countries is essential. Research investments in developing countries will create mutual long-term political, economic and social benefits. Further support for researchers with international expertise is able to expand collaborations and hence benefit others. Particularly in the areas of human health and agricultural research, increased research capacity in developing countries will enable researchers in developed countries to conduct research in those developing countries. Providing short-term training grants for tomorrow's leaders in the less developed world would enhance political ties and allow greater access to those countries in the future.

6.2. National Level

Issues with significance in each country and even in each continent differ. Defense, health, water supply, development of resource and agricultural industries are some 'big ticket items' in which national governments and regional organizations are obliged to invest substantial funds. Thus each country has its own research needs. Research funds in local areas of interest could also be used to attract international research collaboration. Provision of government funding is the starting point for international scientific collaboration. On the other hand, research outcome in projects need to be monitored to determine whether funding is being used productively and whether ongoing funding is warranted (e.g. science advisory board assessments). Some strategies that can be implemented, particularly in developing countries, are described below.

6.2.1. Develop National Policies for Stimulating International Research Collaborations

- Governments ought to establish science advisory boards at regional and national levels to ensure that appropriate advice is provided to policy makers. These advisory boards could provide advice on the development of research and innovation in general, and on international research matters including current research trends and priority areas for each nation.

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- Systems must be in place to overcome negative impacts of inter-institutional competition. This will ensure that resources available for international research engagements are used effectively and efficiently in each country.
 - Researchers need access to some discretionary funds (with approved justification) from time-to-time. Some flexibility in spending existing research funds on developing emerging collaborative arrangements may also be useful.
 - Researchers at all levels of their careers need to be supported, not just long-established researchers.
 - Governments ought to maintain a balance between support for a wide range of relevant international research collaborations, rather than concentrating funding on 'big ticket' political or populist issues.
 - Active pursuance of bilateral government agreements with matching funds can greatly facilitate collaborations. This strategy has recently been implemented by the Australian government as evidenced by the bilateral agreements with China and India.
 - Scientists should be encouraged to consider bilateral agreements when undertaking international research. National funding agencies may usefully provide a system whereby a researcher or group of scientists can propose a bilateral agreement with a particular country to capitalize on opportunities that may emerge from clustered research collaboration. Bilateral agreements should target institutions that are geographically well-distributed throughout the world.
 - Small grants/funds should be made available to invite retired and renowned scientists to visit research groups and postgraduate students who would benefit from their scientific experience.
 - Science and innovation investment programs require five, ten, and even fifteen-year plans. Changing governments need to continue to support established programs from previous administrations.

6.2.2. Develop Human Resources and Infrastructure

- Sustained suitable collaborative research infrastructure investment in a country or region needs to proceed in parallel with the development of a capable work force and associated supporting organizations. This balance is particularly important for developing countries to retain new staff trained in overseas laboratories. Such staff demands laboratories and facilities to initiate research using new skills gained from their training.
- Identification of a few key institutes with extensive international research collaborations, ensuring that their experience benefits capacity building for others in the country may be a good strategy, particularly for developing countries. These institutions need to be well-supported to maintain ongoing collaborations. The strategy of establishing world-class research centers where a niche technology or area of research expertise generates outputs for all partners has been implemented in several countries such as Australia, Singapore, USA and Germany.
- Foster strategies for implementing initiatives that ensure a capable scientific workforce is available in perpetuity.

- Provide PhD scholarships specifically for internationally collaborative projects allowing joint supervision; students benefiting from the best brains in the world will help build further international collaborations. Making such funding available to other nationalities is essential in order to access a large pool of candidate students with the hope that few of them become the next generation of world leading scientists.
- Developing countries in particular may establish special programs to attract their own nationalities with successful track-records back to their home country. For example, China recently implemented 'The Thousand Talent Program' which attracted >600 overseas scientists while offering unprecedented incentives and salaries. Similarly, the Australian Research Council has put in place a Federation Fellow Program to attract successful Australian scientists from overseas to an institution in Australia.
- Universities should prerequisite for every PhD candidate to gain overseas experience, or at a minimum, some research experience in an institute other than the one they graduate from. This could be anywhere from one month to one year training; preferably one year as that would allow students to conduct a meaningful collaborative research.

6.3. Institute Level

6.3.1. Establish Bilateral Agreements

Student and staff exchange programs are becoming increasingly prevalent worldwide. For example, the EU's Erasmus Program (European Region Action Scheme for the Mobility of University Students), established in 1987 as a student exchange program, allows students within EU countries to spend 3–12 months in another country and institution. Reciprocal student exchange programs have been increasingly popular among institutions in the USA, UK, Europe and Australia.

Establishing MOUs are powerful ways of engaging and preparing a working ground for researchers to initiate joint research projects. These agreements may cover joint research grants, fellowships, and support for meetings and conferences. The Chinese government has been extensively implementing this strategy in recent years while signing over 100 MOUs with international institutions (The Royal Society, 2011). The common institutional fear of losing intellectual capability from increasingly high researcher mobility may be somewhat offset by an increased focus on generating joint-research that such mobility provides (Jonkers & Tijssen, 2008).

It is also important to develop a system whereby a researcher or group of scientists proposes a bilateral agreement with a particular international institute to capitalize on opportunities that emerge as a result of research collaboration.

6.3.2. Become Internationally Focused

Building a research team with international experience is extremely important for global R&D competitiveness. Ensuring that new positions are filled with global-minded research staff with good track-records and international work experience ought to be an essential

criterion when hiring new staff. Establishment of an international research management group may also be necessary to set a direction and oversee international relationships. Some universities in Australia and few other countries have established Deputy Vice Chancellor or Vice President Positions that specifically oversee international activities.

6.3.3. Additional Strategies

- Actively promoting relevant leaderships in national and international platforms through partnerships, and encourage visits from international scientists. For example, in the area of agricultural research, scientists should be encouraged to visit the Consultative Group on International Agricultural Research (CGIAR) Centers as many global-minded researchers work in one environment, providing many collaborative research opportunities,
- Encouraging research leaders to collaborate with other national and international institutes by identifying complementary skills in relevant areas,
- Establishing publication support team (particularly in non-English speaking countries) to assist researchers to publish and present their research outputs/products as publications and presentations in national and international platforms for worldwide impact,
- Ensuring that staff with international opportunities also have good cultural training,
- Developing research culture amongst young Masters and PhD students, and postdoctoral scientists so they can work/conduct research for further professional development anywhere in the world,
- Encouraging staff to lead and organize national and international workshops and conferences, which would promote the brand name and research conducted within an institute, enabling research staff to build new contacts and hence establish new research collaborations.

6.4. Researcher Level

When establishing international research collaboration, interpersonal skills are important for building goodwill among peers through professional engagements and communications. These preliminary collegiate and professional relationships become extremely important in establishing active research collaborations.

Strategies may differ for a PhD student or early-career researcher compared with an experienced researcher with an excellent track-record. Experienced and well-published researchers generally have many established international linkages. For further collaborative research development, taking sabbatical in a developed or less-developed country may allow senior researchers to learn and understand more about research capacity and dynamics/politics in that country. This information may help them to refine their research programs while building new partnerships in that country. Another useful approach for the experienced researchers may be of developing a new initiative(s) and/or research tool(s) in an innovative niche area, which may be needed by other international groups, thereby allowing them to engage with other national and international groups. In the new initiatives, inclusion

of PhD research projects that involve co-supervision with international partners may facilitate new research collaborations.

A key step towards establishing international cooperation is getting to know peers in the same research field. Publications, particularly for PhD students and early career researchers, are a good vehicle for introduction to others although other interpersonal skills are required to build further communications that may lead to research collaborations. It is preferable that PhD students are encouraged to engage in the formal peer-review journal publication process during their candidature, prior to thesis submission, and further seek post-doctoral studies with well-established research groups in world-class institutes. One useful approach towards getting a postdoctoral position at a more established laboratory may be by way of making the initial inquiry with a concept note for a research problem.

Maintaining international research relations can be extremely demanding and requires occasional face-to-face meetings. One way to maintain existing relationships and initiate new ones is to attend national and international meetings and conferences where many like-minded researchers gather.

Addressing the complex, evolving challenges within a globalised context will require international collaborative research, and developing nations are now expected to engage in agricultural research and education. To increase capacity to undertake such research and education will, in turn, require the development of global networks for international collaboration.

CONCLUSION

Solutions for global challenges such as poverty, climate change, animal and human health, food security and biosecurity often require complementary skills and facilities that exist in different geographical areas, and sectors outside of conventional research specializations. Harnessing agricultural expertise from across the world often necessitates collaborative arrangements with scientists from both developed and developing countries. Fundamentally, policy makers must ensure that *appropriate* collaborative activities occur that clearly increase research productivity as opposed to stifling it (Duque et al., 2005). This is particularly important in resource-constrained institutions in less-developed countries where inappropriate collaborative activities may *decrease* research productivity (Ynalvez & Shrum, 2010).

The primary purpose of this chapter was to outline key drivers, benefits, and impediments of international research collaborations, and provide a number of strategies that may be implemented to enhance successful international research collaborations at a range of levels: global, national, institutional, and researcher. This work shows that benefits derived from participating in international research collaborations differ at the global, national and regional level, and also at the institutional and researcher level. The key driver at every level is to create collaborations that are more prosperous, productive, and internationally competitive. Investing in collaborations between developed and developing countries is essential in creating mutual long-term political, economic and social benefits. The improved research capacity in developing countries enables researchers in developed countries to conduct research in developing countries, resulting in additional improvements in capacity. Thus, the

provision of short-term education and training funding for tomorrow's leaders in developing countries enhances the long-term national research capacity, and also socio-political ties between countries into the future.

At its most basic, ensuring continuity of productive collaborative education and research fosters personal links, shared professional interests, and an ongoing supportive framework (Shore & Groen, 2009). As research and education institutions redefine their broader social role and their relationships between numerous stakeholders (Jongboed et al., 2008), the scientific enterprise will be heavily influenced by the availability of skilled scientists, technicians, managers, and also serendipity (Organisation for Economic Cooperation and Development, 2006; Arundel & Sawaya, 2009). Clearly, the global research endeavor will gain immensely by developed nations enabling the often nascent collaborative capacity of developing nations to raise the standard of living of their large, commonly agrarian populations.

ACKNOWLEDGMENTS

Authors give their sincere thanks and appreciation to Neil Turner from The University of Western Australia, Philip Day from The University of Manchester, Rajeev Varshney from The International Crops Research Institute for Semi-Arid Tropics, and Jen McComb from Murdoch University for their constructive comments on the manuscript.

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