Chapter VII : Technology transfer: Non-monetary benefit-sharing in support of conservation and sustainable use of PGRs

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Key messages

- Non-monetary benefits of the International Treaty on Plant Genetic Resources for Food and Agriculture include germplasm-based and non-germplasm-based technologies.
- The transfer of PGR-related technologies is often on an ad hoc basis.
- Technologies are important for ensuring national and global food security as they facilitate and accelerate the flow, exchange, and use of germplasm.
- South–South and horizontal technology transfers are preferred because of the lower cost of transfer and faster diffusion as well as better adaptation to local contexts, compared with North–South and vertical transfers.
- It is easier and faster to transfer germplasm-based technology than non-germplasm-based technology, but the latter is required for sustainable use of the former.
- Transfer of germplasm-based technologies are accelerated and facilitated by the associated non-germplasm based technologies.
- The flow of non-germplasm based technologies from Nepal's national research organizations to private and farmers' cooperatives is very limited.

The International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA) calls for technology transfer as a primary form of non-monetary benefit-sharing (Article 13.2.b), backed by information exchange (Article 13.2.a) and capacity building (Article 13.2.c) (FAO 2004). Technology transfer is also envisaged by other international agreements, such as the Convention on Biological Diversity (United Nations 1992), and the ITPGRFA reinforces the provisions of the CBD on this subject.

There is concern that although the World Trade Organization's Agreement on Trade-Related Aspects of Intellectual Property Rights promotes technology generation, it hinders technology transfer through protection of intellectual property rights (IPRs), especially with respect to transfer to developing countries, such as Nepal. The agreement requires protection of the rights of breeders to new varieties they develop, but does not require transfer of technology to those who provide the genetic resources, i.e., the farmers.

The ITPGRFA provides that transfer of technology to countries shall be carried out through partnerships in research and development (Article 13.2.b.iii). Priority is given to "the implementation of agreed plans and programmes for farmers in developing countries who conserve and sustainably utilize plant genetic resources for food and agriculture" (Article 18.5).

The governing body of the ITPGRFA has called for measures to realize effective technology transfer and has invited contracting parties and other relevant stakeholders to explore innovative benefit-sharing measures in the area of technology transfer. The objective of technology transfer is to promote the co-development of technologies, recognizing that technology transfer requires a range of supporting activities: building individual and institutional capacity; mobilizing in-kind contributions from both the public and private sectors; and supporting implementation of the treaty. The treaty emphasizes that technology transfer is required to enhance the capacity to use PGRs through plant breeding, using modern tools, traditional varieties, and the participation of farmers.

However, there is considerable uncertainty about what is meant by technologies "for conservation, characterization, evaluation and use" and which technologies developing countries are interested in getting access to (or providing). Nor is there much documentation of the experiences of developing countries, such as Nepal, in their past efforts to transfer (as providers or recipients) such technologies, particularly under the framework of the ITPGRFA. To date, there has also been no discussion about how to operationalize Article 13.2.b at the level of the treaty's governing body. In short, very little is being done to take advantage of the technology transfer provisions of the treaty.

This chapter deals with potential and promising technologies that stakeholders in Nepal believe can be transferred to generate non-monetary benefits to farmers, agro-entrepreneurs, and other stakeholders who support the conservation of PGRs. We also describe key organizations and actors involved in developing and transferring these technologies, the mode and pathways of transfer, and the use of the technologies for conservation, characterization, and evaluation. We hope this information will stimulate discussion, both within countries and at the level of the ITPGRFA's governing body, about Nepal's conceptions of what technologies fall within what is described in Article 13.2.b and developing countries' needs or capacities to transfer such technologies and generate non-monetary benefits.

Our study involves three key components: organizational case studies; practical experiences in technology transfer, including mechanisms and their application; and assessment of the need for various types of technologies.

Research methods

We conducted a literature review, carried out key informant interviews, and held focus group discussions with farmers and a consultation meeting with key stakeholders. We did both organizational studies and technology case studies, conducted a needs assessment among national stakeholders, and examined actual field-level technology transfer status.

Conceptualization of technology types

First, we reviewed relevant literature and consulted experts to conceptualize and study concepts of technology in relation to conservation, characterization, evaluation, improvement, and use as per the provisions of the ITPGRFA. This process helped us identify and categorize potential technologies to focus on for further study (**Table** 7.1). Two types of technologies were identified: germplasm-based technologies, such as high-yielding crop varieties, hybrids, and pre-breeding genetic materials; and non-germplasm-based technologies, including mainly advanced tools and techniques used in the development, characterization, conservation, and evaluation of germplasm technologies.

Table 7.1. Characterization of technology types

Type of technology	Application			
	Conservation	Characterization	Evaluation/ improvement	Direct Use
Germplasm-based (high-yielding varieties, hybrids, pre-breeding materials)	Yes	Yes	Yes	No
Non-germplasm-based (molecular markers, in-vitro propagation techniques, climate analogues tool)	Yes	Yes	Yes	No

Organizational case studies

Following the literature review and conceptualization and categorization of technologies used for two important crops (rice and potato), we surveyed the main research organizations involved in accessing technology from international sources. These are research branches of the Nepal Agricultural Research Council (NARC): the National Agricultural Genetic Resources Centre, the Agricultural Botany Division (ABD), the Biotechnology Research Division, the Seed Science and Technology Division, the National Potato Research Program (NPRP), the National Rice Research Program (NRRP), and the Regional Agricultural Research Station (RARS). We also surveyed an extension organization of the Department of Agriculture: the National Potato Development Program. The survey collected information on the organizational mandate, history, strengths, links, experiences, and lessons learned in the types of technologies they use.

Field surveys of researchers, extension agents, farmers, and private-sector organizations

We conducted key informant interviews of researchers, extension agents, and private-sector organizations (seed companies and tissue-culture laboratories) involved in technology testing, production, and transfer of both germplasm-based and non-germplasm-based technologies. The main private-sector organizations surveyed were Malla Seed Producers Ltd., Chitwan;

Lumbini Seed Company, Rupendehi; Nepal Seed Production Centre, Godavari; and White House College, Lalitpur.

The field survey also included focus group discussions with selected farmers' groups that are involved in the production, multiplication, evaluation, transfer, and use of germplasm-based technologies. They were Sallesh Phulbari Seed Producer Group, Siraha; Bodhimai Seed Producer Cooperative, Kalaiya, Bara; and Unnat Seed Producer Group, Patihani, Chitwan, for rice; and Pragatishil Krishak Samuha, Nala, Kavre, for potato.

In addition, the team also interacted with 20 key informant farmers engaged in seed production, evaluation, and the use of the Swarna Sub-1 variety of rice and pre-basic seed (PBS, also called mini tuber which is equivalent to breeder seed) technologies for potato breeding in Chitwan, Bara, Mahottari, and Siraha. A few seed dealers (agrovets) were also surveyed in Chitwan in the central terai and Kaski, Pokhara, for their perceptions and marketing practices on germplasm-based technologies (rice and potato seeds). The relations between the organizations and actors surveyed are represented in **Figure** 7.1.

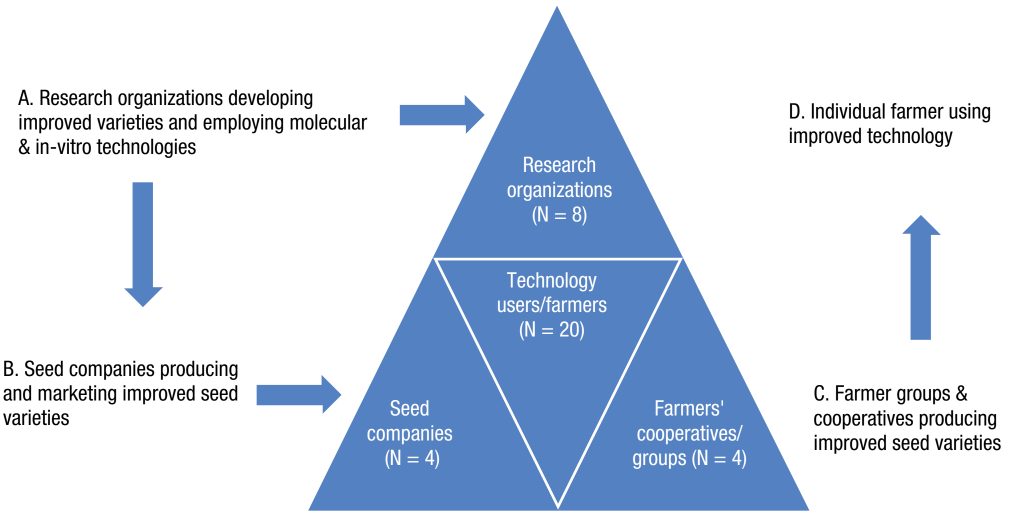

Figure 7.1. Organizations and actors involved in the transfer of technology related to plant genetic resources for food and agriculture.

Technology transfer case studies

Based on the technologies identified in the literature review and organizational studies, we chose one technology used in rice breeding (Swarna Sub-1) and one used in tissue-culture of potato. We studied these for their transfer priorities, mode and pathways of transfer, and experience gained in the country from the transfer process. Both germplasm-based and non-germplasm-based technologies and their transfer process were studied.

As part of the case studies, we also assessed the technological needs of national stakeholders engaged in developing, transferring, and using new technologies.

Concept of technology and technology transfer

The word “technology” refers to the making, modification, use, and knowledge of tools, machines, techniques, crafts, systems, and methods of organization to solve a problem, improve an existing solution, achieve a goal, or perform a specific function (Wikipedia 2015). The word technology comes from two Greek words: techne meaning art, skill, craft, or the way, manner, or means by which a thing is gained and logos meaning, the utterance by which inward thought is expressed, a saying, or an expression. So, literally, technology means words or discourse about the way things are gained.

“Technology transfer” is the process of transformation of the results of research and development (R&D) into marketable products or services. The National Science Foundation defines technology transfer as the exchange or sharing of knowledge, skills, processes, or technologies across different organizations. It also refers to the process by which science and technology are transferred from one individual or group to another that incorporates it into a new or improved process, product, system, or way of doing something (Marthniuk et al. 2003). It relates to lawful delegation of IPRs to technology developed by one party to another. Technology transfer is a process through which technical information and products developed by the R&D agencies are provided to potential users in a manner that encourages and accelerates their evaluation or use. Technology transfer in relation to the ITPGRFA encompasses commercial and non-commercial aspects of sharing technologies relating to genetic resources and bioprospecting (FAO 2004). The transfer of technology is, thus, a means of sharing the benefits derived from the sharing of the genetic materials under the MLS.

Technology transfer can be done in various ways. Some widely recognized models (Ruttan and Hayami 1973, Tenkasi and Mohrman 1995, Rogers 2003, Sung and Gibson 2005, Choi 2009) are:

- The appropriability model — Purposive attempts are unnecessary for technology transfer because “good” technologies sell themselves.
- The dissemination model — Transfer processes will be successful when experts transfer specialized knowledge to prepared beneficiaries.
- The knowledge utilization model — Emphasizes strategies for effective delivery of knowledge to beneficiaries.
- The contextual collaboration model — Accentuates the idea that knowledge cannot be simply transmitted, but must be subjectively constructed by its recipients.
- The design transfer model — Focuses on the transfer of blueprints and specifications, along with the technology itself.
- The capacity transfer model — Stresses the transfer of knowledge to give recipients the capability to design and produce a new technology on their own.
- The material transfer model — Transfer of new materials, such as machinery, seeds, tools, and the techniques associated with their use.

In this study, we focus mainly on the material transfer model, related to the transfer of PGRs and information, techniques, knowledge, and skills associated with their use. This model is the main driver of innovations related to bioprospecting. Such innovations can create new knowledge and technology that can be transferred through a model appropriate to agricultural development (Biggs

1989). Theories of international technology transfer often focus on the transfer of production-related technologies that are of immediate benefit to the users (Tsang 1997). International technology transfer is mainly concerned with transferring technology related to livelihoods from developed to developing countries to contribute to the reduction of poverty. The MLS is envisaged as a pool of intangibles and a system for the exchange of technologies. Under this system, members are urged to facilitate access to genetic material and related technologies and to improved varieties and genetic materials developed through the use of this system (Article 13.2.b.i).

However, the transfer of technology requires a trade-off regarding the IPRs of its creators. The form of the technology transfer depends on contractual arrangements between the creators and users of the technology and differs from case to case. Contracts identify the technology to be transferred and delineate the terms and conditions of the transfer. Transfer can involve documents, technical services, assistance, or skills training. Contracts for the transfer of PGR technology can be an agreement concerning the licensing of IPRs, such as plant variety patents, *sui generis* protection, plant related trademarks; or a know-how agreement involving the transfer of data, information, manuals, instruction, breeding methods, protocols, or production skills that are not in the public domain.

Categorization of technologies

Technologies can be categorized based on their nature, use, and transfer process. Moore and Tymowski (2005) suggest two broad types: soft and hard technologies. Soft technologies include knowhow, techniques, and skills, such as conservation techniques used in a particular farming community or new biotechnological techniques developed by researchers. Hard technologies include tangible goods, such as equipment, hardware, or seeds from a particularly plant variety developed by a farmer or breeder. Hard technologies are rarely transferred without some form of accompanying soft technology. These technologies may be transferred through research collaboration, reforming foreign direct investment laws, tax and other incentives, joint ventures, grants, expanding IPRs, establishing a technological clearinghouse, or other mechanisms.

Technology transfer under the ITPGRFA

The ITPGRFA envisages the transfer of technology through crop-based thematic groups, research and development partnerships, and commercial joint ventures (FAO 2004). The treaty also emphasizes that the process should be "on fair and most favorable" and "concessional and preferential" terms that also recognize and are "consistent with the adequate and effective protection of IPR."

Article 7.2 of the treaty mentions international cooperation in sharing, providing access to, and exchanging PGR-related information and technology. Likewise, Article 13.2 requires that benefits arising from the use of PGRs under the MLS be shared fairly and equitably through one or more of four mechanisms: exchange of information; access to and transfer of technology; capacity-building; and sharing of benefits arising from commercialization. Some mechanisms are stipulated for access to and transfer of technology relating to PGRs.

First, access to technologies for the conservation, characterization, evaluation, and use of PGRs will be provided and/or facilitated under the MLS. Second, access to and transfer of technology to countries, especially developing countries "shall be carried out through a set of measures, such as the establishment and maintenance of, and participation in, crop-based thematic groups on utilization of plant genetic resources for food and agriculture, all types of partnership in research and development and in commercial joint ventures relating to the material received, human resource development, and effective access to research facilities." Third, access to and transfer of technology relating to PGR under the MLS, including that protected by IPRs, to developing countries shall be provided and/or facilitated under fair and most favourable terms. This applies especially to conservation technologies as well as technologies that benefit farmers in developing countries through increased crop production. It also includes technology transfer on concessional and preferential terms through partnerships in R&D under the MLS. However, transfer must respect applicable property rights and access laws and be in accordance with national capabilities. In addition, the terms of access and transfer will recognize and be consistent with adequate and effective protection of IPRs.

Weak regulations governing property rights and delay in the development of laws surrounding access to PGRs make developing countries like Nepal vulnerable to pressure from other members. In recognition of this, the ITPGRFA includes the issue of national capabilities. However, it is not clear how weak national capabilities will be respected by other members in the case of technology transfer. The treaty also requires adequate and effective protection of IPRs during technology transfer. Such conditions facilitate the transfer of the technology from a country whose technologies are in the public domain or have weak IPR laws to a country whose technologies are in the private domain, but not vice versa. This puts Nepal, a country whose technologies are mainly in the public domain, at a disadvantage under the international system of technology transfer envisaged by the treaty.

Selected technologies

As described above, germplasm-based technologies include improved seed varieties, hybrids, pre-breeding genetic materials, such as PBS technologies for potato breeding, submergence-tolerant rice varieties (Swarna Sub-1), etc. Non-germplasm-based technologies include those related to processes, tools, and techniques, such as biotechnological tools and advanced techniques for germplasm characterization, conservation, improvement, and use. These may include molecular markers (e.g., simple-sequence repeat [SSR], Random Amplified Polymorphic DNA [RAPD], and single-nucleotide polymorphism [SNP]) and in-vitro/micro propagation of food and horticultural crops. The transfer of many important germplasm-based technologies under the MLS is accelerated or facilitated by non-germplasm-based technologies.

For the case studies, we selected a combination of germplasm and non-germplasm-based technologies, as both types are needed for better promotion and transfer (**Table** 7.2). The specific non-germplasm-based technologies were the application of molecular markers to drought and flood tolerant varieties and in-vitro propagation for PBS production of improved potato varieties from the national commodity research programs at NARC.

Table 7.2. Cases of technologies and commodities selected and investigated

Commodity	Technology for transfer	
	Germplasm-based	Non-germplasm-based
Rice	Drought and flood tolerant rice varieties (e.g., Swarna Sub-1)	Molecular marker (e.g., SSR marker) technique
Potato	PBS-improved potato varieties	Micro-propagation (in-vitro) technique

Mechanisms and pathways of technology transfer

National laws in Nepal do not identify the entity with the authority to grant access or authorize transfer of genetic materials; thus, the transfer of PGR-related technologies is done on an ad hoc basis. We documented profiles of key research organizations, their current research mandate, technology development, conservation, characterization, and evaluation processes and studied the mode and pathways of transfer of important technologies. We prepared:

- Profile of NPRP's work in in-vitro propagation covering PBS technologies for improved potato varieties.
- Profiles of rice research institutions, such as NRRP and the Agricultural Botany Division of NARC in terms of access and transfer of flood-tolerant Swarna Sub-1 along with its marker assisted selection technology.
- Profiles of private-sector and farmers' organizations in terms of their access to and availability of technologies and their modes of transfer and use.
- Successful cases, transfer trends, and activities of the organizations and modes of technology transfer with other organizations and actors.

Technology transfer is a complex and dynamic process that is affected by many factors and actors and occurs through various modes, pathways, channels, and networks (Gauchan 2008). Transfers may be vertical or horizontal, direct or indirect, from North to South or South to South (**Table** 7.3). They may include the transfer of technologies from public to private or private to private organizations. They may also include, through collaborative agreements, foreign direct investment in the form of special projects, crop-based thematic groups, consortia, exhibitions, training, workshops, etc.

Table 7.3. Modes of technology transfer for various technology types

Technology	Donor	National institution/ recipient	Local institution/ recipient	Transfer mode / mechanism
Swarna Sub-1 rice	IRRI	NARC (NRRP/ABD)	Seed companies	SMTA
Molecular marker	USA/Japan to IRRI	NARC (ABD)	Other public research organizations (e.g., NARS)	FDI/interna-tional project support
Kufri Jyoti and Janakdev potato varieties	CIP	NARC (NPRP)	Extension organizations (DADO)	Free
In-vitro propagation	CIP/SDC	NARC (NPRP)	Farmers' groups, cooperatives, private institutions, seed companies	MoU with SDC for technical project support

Note: ABD = Agricultural Botany Division, CIP = Centro Internacional de la Papa, DADO = District Agriculture Development Office, FDI = Foreign Direct Investment, IRRI = International Rice Research Institute, MoU = Memorandum of Understanding, NARC = Nepal Agricultural Research Council, NARS = Nepalese Agricultural Research System, NPRP = National Potato Research Program, NRRP = National Rice Research Program, SDC = Swiss Agency for Development and Cooperation, SMTA = Standard Material Transfer Agreement, USA = United States of America.

The generic mechanisms currently being adopted for technology transfer related to PGRs for food and agriculture in Nepal are represented in **Figure** 7.2. Most advanced and scientific technologies (molecular markers, in-vitro propagation, and other biotechnological techniques) and products derived from their applications (e.g., PBS potato production, Swarna Sub-1 rice, etc.) are being transferred from international to national research organizations and, with some modifications or testing, they are then being transferred to extension organizations and /or cooperatives and private-sector organizations (seed companies, private laboratories, etc.). Finally the technological products are transferred to farmers and users.

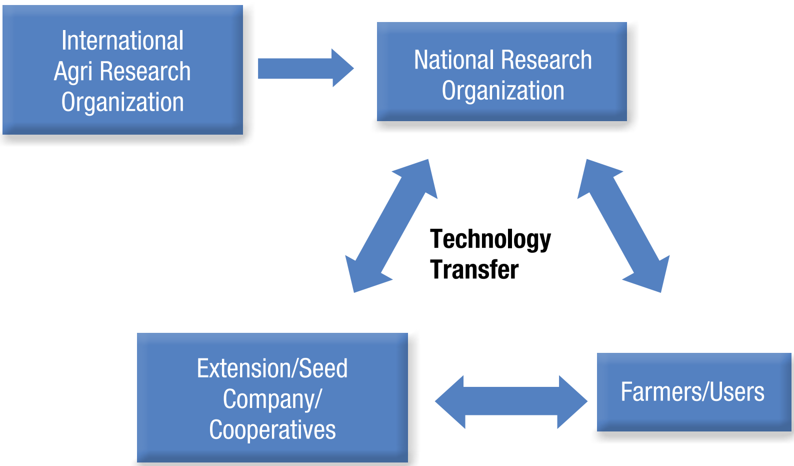

Figure 7.2. Mechanisms of current technology transfer of PGRs for food and agriculture in Nepal.

North–South and South–South transfers

Many advanced technologies, both germplasm-based (e.g., high-yielding crop varieties, pre-breeding materials) and non-germplasm-based (e.g., molecular markers, in-vitro propagation) are currently being transferred from developed to developing countries, mainly through international research centres and universities. For instance, molecular marker technology for the development of Swarna Sub-1 was transferred from the United States to the IRRI, then to a national research institution, such as NARC, and, finally, to users (farmers) through various pathways and channels. Similarly, in-vitro propagation techniques for PBS potato production in Nepal was transferred from Switzerland to NARC through a project funded by the Swiss Agency for Development and Cooperation. Some of these technologies, once adapted, are also being transferred from South to South. For example in-vitro PBS potato propagation technology is being transferred from Nepal to Bhutan and the Swarna Sub-1 rice variety from India to Nepal.

Vertical transfers

Vertical transfer is mainly from international centres to national research centres and laboratories, and then to extension organizations and, finally, farmers. This type of transfer has been observed commonly for PBS improved potato varieties in Nepal. Molecular marker technology, currently adapted and promoted by NARC research bodies, was first introduced from international research organizations and developed countries of the North.

Currently, NPRP develops PBS of improved varieties in its research laboratory at Khumaltar, Lalitpur, which are then provided to district agriculture development offices, the agricultural extension system in Nepal. The district offices then distribute the PBS potatoes to farmers' groups and cooperatives through their regular extension methods and district network.

Horizontal transfer

Horizontal transfer takes place from one national organization to others at the local level within the country. This is common in the case of transfer of molecular-marker technologies (e.g., SSR marker) in rice and in-vitro propagation technology for potato. For instance, molecular-marker technology currently in use by NARC was first introduced and adapted by its Agriculture Botany Division in 1998. Gradually, this technology was transferred to other NARC research organizations (e.g., National Agricultural Genetic Resources Centre, the Biotechnology Research Division, and the Seed Science and Technology Division) as well as other institutions in Nepal. Similarly, in-vitro potato propagation technology is being transferred from NPRP to other research organizations, including private-sector and farmers' groups. The in-vitro technology being adopted for PBS production at the Nepal Seed Production Centre, Godavari, White House College, Lalitpur, and Pragatishil Yuba Krishak Samuha, Nala, Kavre, was transferred from NPRP in the last few years.

Direct and indirect pathways

Direct pathways for technology transfer include collaborative research as well as foreign direct investment agreements or contracts between organizations, institutions, and stakeholders. For example, inbred parental material for hybrids is being transferred from private multinational companies to national research centres under research agreements. Currently, germplasm is being transferred from CGIAR organizations to the Nepalese agricultural research system through Standard Material Transfer Agreements implemented under the ITPGRFA.

Some germplasm-based technologies (e.g., new crop varieties) are also being transferred from international and national research institutions to community-based organizations through participatory action research, such as participatory plant breeding and participatory variety selection. The pathway was through training and PhD work by NARC researchers at IRRI and subsequent training provided by these researchers to farmers, seed companies, and extension workers in Nepal in seed production and participatory varietal selection.

Both germplasm- and non-germplasm-based technologies are also transferred through indirect pathways. The most common include research publications, training, and information flow through mass media and networking.

Transfer through public–private partnerships

Many germplasm-based technologies related to crop varieties developed in public research organizations (e.g., NARC) are being transferred to private organizations (e.g., seed companies) through this partnership mode. Currently, NARC has initiated transfer of parental inbred lines of maize hybrids to private companies (e.g., the Seed Entrepreneurs' Association of Nepal) through formal agreements or memoranda of understanding. Technology for hybrid vegetable seed production and genetic materials, such as the Srijana tomato developed at NARC has also been transferred to private organizations and NGOs, such as in Gorkha Seed Company, Anamolbiu, and Center for Environmental and Agricultural Policy Research, Extension and Development (CEAPRED).

Technology transfer case studies

PBS tissue culture of potato

Tissue culture is one of the most popular technologies in Nepal as it allows production of virus-free potato seeds. Researchers believe that the basic potato seed remains virus free for five generations before becoming susceptible. Tissue culture (or in-vitro propagation) of potatoes was first started in 1989 by the National Potato Development Program (NPDP) with the technical and financial assistance of the Swiss Agency for Development and Cooperation. Research on varietal development and testing was later supported by the Centro Internacional de la Papa, Peru.

NPRP was established in 1992 to carry out the research activities of NPDP. Since then, NPRP has been the main organization involved in the development of new varieties and the production of disease-free potatoes through in-vitro propagation. The technology has been transferred to farmers by various modes and pathways, mainly through the district agricultural extension programs of the Department of Agriculture, in which NPRP plays facilitating role. In-vitro propagation technology has also recently been transferred from NPRP to private-sector organizations and farmers' groups who are supplying PBS potatoes to farmers through the agricultural extension system. In the early 1990s, the technology was also transferred from Nepal to neighbouring Bhutan, through technical support and training of Bhutanese researchers at NPRP in Kathmandu (B Khatri, NPRP, personal communication). A recent example of technology transfer of PBS technology from NPRP to a farmers' group is presented Box 1.

Box 1. PBS technology transfer: Pragatishil Yuba Krishak Samuha, Nala, Bhaktapur

Pragatishil Yuba Krishak Samuha (13 members: 11 men and 2 women) was established in 2007. It has been producing pre-basic potato seed since 2008 in a greenhouse with the support of NPRP. The group has built a tissue-culture laboratory, which was completed in 2012, with financial support from the District Development Committee, Kavre, and the Project for Agriculture Commercialization and Trade. In 2013, the group produced 17500 potato cultures, which are being stored in a rented facility, Bagmati Cold Storage, Bhaktapur. The varieties in production are Janakdev, Kufrijyoti, Cardinal, Disere, Khumal Laxmi, Khumal Seto.

In 2014, the group aimed to produce 100000 cultures in two seasons. The potato varieties produced were supplied to district agricultural extension offices through NPRP based on demand at the remote mountain district offices of Humla, Jumla, Mugu, and Solukhumbu. The group estimates that almost 80% of potato growers in the Nala area use basic seeds, which can produce almost double the crop of traditional varieties. The tissue-culture lab is supervised by a technician with a master's degree in biotechnology.

PBS potato technology has recently also been transferred from NPRP to private organizations, such as the Nepal Seed Production Centre, Godavari; the private White House College, Hattiban. The technology transfer program and operations in the private sector have been functioning well (Box 2).

Box 2. PBS technology transfer: Nepal Seed Production Centre, Godavari, Lalitpur

This seed production centre was established in 2002 with technical support and technologies from NPRP. It has a tissue-culture laboratory and has been producing PBS potatoes for the last two years (2012/13–2013/014). The centre is run by 11 women members with technical and managerial support from an NPRP trained staff technician (Mr. Ram Varosa), who also sits on the centre's member advisory group.

The centre's annual production target is 100000 PBS in two seasons. It deals mainly with released and recommended varieties, such as Janak Dev, Desire, Cardinal, Khumal Laxmi, and Khumal Seto. After harvest, PBS is stored at Balaju Cold Storage as the centre does not have its own cold storage facility. The centre plans to sell the PBS in October to the National Potato Development Program of the Department of Agriculture. From there, seeds will be transferred to farmers' groups and cooperatives across Nepal for general cultivation.

Currently, the PBS produced at this centre goes to 19 districts of Nepal where the Potato Seed Self-sufficiency Program is being implemented through district agricultural development offices. The Potato Development Program then collects orders from district agriculture development offices across the country for which different classes of seeds (e.g., foundation seeds, certified seeds, etc.) are produced after PBS. But the current practice is that not more than one generation of seeds is produced as the seed chain is yet to be fully established.

Swarna Sub-1 rice

Swarna Sub-1, a flood-tolerant variety of rice, was developed at IRRI during the early 2000s (2001–2005) through marker assisted selection (MAS). It was derived by incorporating a submergence-tolerant gene (Sub-1) into a widely grown Swarna variety from India through marker-assisted back-crossing. Swarna Sub-1 rice is tolerant to flooding for up to 2 weeks, an important trait as water stagnation and flash flooding are common problems in Asian lowlands.

Swarna Sub-1 was transferred from IRRI to Nepal and other South Asian countries through various channels as part of IRRI's Stress-Tolerant Rice for Africa and South Asia project. In Nepal, the transfer was to NARC and evaluation was carried out by the NRRP at Hardinath and the RARS in Tarahara in both flood-prone and other areas before its release in 2011. The variety is being promoted by the NRRP and RARS (Tarahara) as well as other NARC research organizations to farmers in flood-prone and other areas through multiple pathways (agricultural extension, seed companies, community-based seed producer groups, and cooperatives). Swarna Sub-1 varieties are being produced and marketed by several private seed companies, farmers' groups, and cooperatives in various parts of Nepal with NARC's technical support and provision of source seeds. Evidence of technology evaluation, multiplication, and transfer at the field level is presented in Box 3.

Box 3. Transfer of Swarna Sub-1: the Shallesh Seed Producer Group, Siraha

The Shallesh Seed Producer Group was established in 2008 by the Padariya Village Development Committee in ward 3 of Siraha district as a community-based seed producer group. The group has 25 members who are engaged mainly in rice and wheat seed production. Since 2010, it has been receiving regular technical support and source seeds from RARS, Tarahara.

Using breeder seed of the Swarna Sub-1 variety from RARS, the group has engaged in production, multiplication, and marketing of foundation, certified, and labeled seeds of Swarna Sub-1 and other rice varieties, such as Sukha-2, Sukha-3, Hardinath-1, Sona Masuli, and Kanchhi Masuli. In 2011/12, it produced about 20 Mt of rice seeds, of which about 2 Mt were the Swarna Sub-1 variety. The foundation seed that is produced by the group under technical supervision by RARS is certified by the regional seed-testing laboratory in Sunsari, Jhumka, and sold to farmers' groups and cooperatives in Siraha, Saptari, and Dhanusha for the production of certified and improved seeds with the support of the district agriculture development office, Saptari.

This is one of the few successful community-based seed producer groups in the eastern terai that is engaged in source seed production, multiplication, and the transfer of new variety technology from NARC research centres to farmers' fields.

The indirect transfer of Swarna Sub-1 seeds from NRRP to farmers' groups and a private seed company is presented in Box 4.

Box4.Transfer of Swarna Sub-1: Unnat Seed Producer Group, Chitwan

Established in 2007, the Unnat Seed Producer Group is a well-known organization with 300 farmer members specializing in grain seed production. Since 2012, it has been receiving breeder and foundation seeds from the NPRP and is producing, multiplying, and marketing seeds of Swarna Sub-1.

In this case, the mode of technology transfer was more indirect, as the NRRP provides only breeder and foundation seeds on demand. The quality-certified and improved seeds produced by this group are transferred to many farmers across Nepal through various marketing and sales outlets. Because of its success in seed production and marketing, the group has been able to secure grants from various organizations, including funding support from the Directorate of Agricultural Engineering of the Department of Agriculture for infrastructure (storage facilities, equipment, and machinery).

The group is also registered as a private seed company for the purposes of marketing its seed. In 2013, it produced 13 Mt of Swarna Sub-1 seeds (including 0.6 Mt of foundation seed) out of its total 534-Mt production of seeds of other improved rice varieties (Sabitri, Radha-4, Ramdhan, Masuli, Sona Masuli, Makawanpur-1, Hardinath-1, etc.). It markets improved and certified seeds through such outlets as agrovets, cooperatives, and district agriculture development offices, ranging from east of Jhapa to the far west of Bardiya district. In the 2014 season, it sold 65% of the volume of its seed to the National Seed Company under a subsidy scheme. Thus submergence-tolerant technology (in the form of the Swarna Sub-1 variety) is being transferred to general cultivation among farmers in many parts of Nepal.

Technology transfer opportunities and issues

Various factors and pathways have been instrumental in the flow of these technologies and the sharing of non-monetary benefits to support conservation of PGRs for food and agriculture in Nepal. The nature of the technology itself, favourable international and national policy environments, and institutional capacity, among other factors, have played an important role in facilitation of technology transfer from North to South and between Southern countries and institutions.

International transfer of PBS potato germplasm across developing countries has been facilitated because of its disease-free nature (resulting in less restrictive quarantine regulations) and provisions of the Standard Material Transfer Agreement (SMTA) under the MLS. This in-vitro propagation technique has accelerated the flow, exchange, and use of PBS-based germplasm technologies in Nepal through developed countries under both the MLS and bilateral means.

Although the demand for PBS potatoes is high among farmers across Nepal, the country is unable to maintain a sufficient supply. The flow of associated non-germplasm-based technologies from national research organizations to private and farmers' cooperatives has been minimal because of the need for relatively high technical skills, resources, and investment in the transfer of the technology. International support, in terms of technical capacity-building and funding, is essential to promote large-scale commercialization of this technology in Nepal.

The international transfer of Swarna Sub-1 germplasm across developing countries was also facilitated through SMTA provisions. Molecular-marker (non-germplasm-based) technology has accelerated the flow, exchange, and use of germplasm-based Sub-1 technologies in Nepal and Asia. However, despite the rapid distribution of germplasm, the flow of the marker-assisted selection technique from IRRI to national research institutions in South Asia has been minimal. The trained human resources, institutional capacity, and investment needed to effectively transfer and promote this technology on a large scale is lacking in Nepal. International support in terms of technical capacity building and funding is essential to promote large-scale commercialization and uptake of this technology in Nepal.

These examples illustrate how the transfer of germplasm-based technologies is easier and more successful in Nepal that that of non-germplasm-based technologies.

Assessment of technology needs, opportunities, and constraints

With the use of traditional farming practices, the low levels of external input, poor-quality traditional varieties, and diverse farm conditions in Nepal, crop productivity is low and the rate of increase is slow. The recommended seed replacement rate for cereals is 25% a year, for example, whereas the existing rate is no more than 12%. Suitable varieties of improved seeds and related technology are necessary to improve the livelihoods of the farmers and grow enough food for domestic consumption. Technology is needed to identify, conserve, and select landraces that can be used to increase productivity and the profitability of farming.

Improved plant varieties and the practices associated with them can increase food production and reduce poverty. However, the low level of education among farmers, the small and scattered nature of their holdings, and the heterogeneity of their farmland are the major constraints on their receiving improved technologies. With such resource constraints, farmers value direct monetary benefits more than technology-sharing in exchange for access to their genetic resources.

Conclusions and way forward

National laws in Nepal do not identify an entity with the authority to grant access to or authorize transfer of genetic materials. Thus, the transfer of PGR-related technologies is done on an ad hoc basis. The transfer of many important germplasm-based technologies under the MLS and bilateral systems is accelerated by some advanced techniques used for conservation, characterization, evaluation, improvement, and use of PGRs. These are process-related technologies and include mainly specific molecular techniques and in-vitro propagation of food and horticultural crops. These technologies are important for ensuring national and global food security as they facilitate and accelerate the flow, exchange, and use of germplasm-based technologies under the MLS, mainly to developing countries.

However, successful and sustained technology transfer requires adoption of a combination of germplasm- and non-germplasm-based technologies. Trained human resources, financial investment, and modern laboratory facilities are needed to apply non-germplasm-based technologies in developing countries. South–South and horizontal technology transfers are preferred because of the lower cost of transfer and faster diffusion as well as better adaptation of PGRs to the local context.

In summary, our key findings on technology transfers as a means of sharing non-monetary benefits for conservation of PGR in Nepal are:

- Germplasm-based technology transfer is easier and faster than the transfer of non-germplasm-based technology, but the latter is required to ensure sustainability.
- Transfer of germplasm-based technologies, such as improved varieties, is accelerated and facilitated when accompanied by the associated non-germplasm-based technologies, such as molecular- marker and in-vitro propagation techniques, used for their conservation, characterization, evaluation, improvement, and use. Hence, successful and sustained technology transfer requires adoption of a combination of germplasm- and non-germplasm-based technologies.
- Trained human resources, financial resources, and modern laboratory facilities are needed to use non-germplasm-based technologies. Despite a high demand for improved germplasm, such as the PBS potatoes, the flow of the associated non-germplasm-based technology (in-vitro propagation) from national research organizations to private and farmers' cooperatives has been minimal in Nepal because of the requirement for relatively high technical skills and resources.

References

Biggs JB. 1989. Approaches to the enhancement of tertiary teaching. *Higher Education Research and Development* 8:7-25.

Choi HJ. 2009. Technology transfer issues and a new technology transfer model. *Journal of Technology Studies* 35:49-57.

FAO. 2004. International Treaty on Plant Genetic Resources for Food and Agriculture. Food and Agriculture Organization (FAO), United Nations, Rome, Italy. http://www.planttreaty.org/content/texts-treaty-official-versions

Gauchan D. 2008. Reforming research and extension systems in Nepal: emerging models of technology development and transfer**.** *Agricultural Development Journal* 4:34-44.

Martyniuk AO, RK Jain and HJ Stone. 2003. Critical success factor and barrier to technology transfer: case studies and implications. *International Journal of Technology Transfer and Commercialization* 2:306-337.

Moore G and W Tymowski. 2005. Explanatory guide to the International Treaty on Plant Genetic Resources for Food and Agriculture. International Union for Conservation of Nature, Gland, Switzerland.

Rogers EM. 2003. *Diffusion of innovations* (5th ed). Free Press, New York, USA.

Ruttan VW and Y Hayami. 1973. Technology transfer and agricultural development. *Technology and Culture* 14:199-151.

Sung T and DV Gibson. 2005. Knowledge and technology transfer grid: empirical assessment. *International Journal of Technology Management* 29:216-230.

Tenkasi RV and SA Mohrman. 1995. Technology transfer as collaborative learning. **In** *Reviewing the Behavioral Science Knowledge Base on Technology Transfer.* TE Backer, SL David and G Soucy (eds). Department of Health and Human Services, National Institutes of Health, Rockville, MD, USA. pp.147-167.

Tsang EWK. 1997. Organizational learning and the learning organization: a dichotomy between descriptive and prescriptive research. *Human Relations* 501:73-89.

United Nations. 1992. Convention on Biological Eiversity. United Nations, New York, USA. http://www.cbd.int/doc/legal/cbd-en.pdf

Wikipedia. 2016. Technology. http://en.wikipedia.org/wiki/Technology.