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Technology Transfer and Commercialization – Innovative Model for Strengthening Research and Industry Linkages and Valuation through Public Private Partnership in Agriculture*

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Innovative technical knowledge, often packaged as 'improved technology' is imperative for agricultural crop productivity enhancement. The effort of technology development is complete only when it is adopted by the end user as a product suitable for commercial application. It is thus important that university/research organizations understand industry needs or work in close collaboration with the industry. With a view to enhance university/research-industry linkages, augmenting 'market driven research' and assigning 'value' to innovative research, universities world-over have initiated technology transfer and commercialization efforts. Public sector lead university/research organizations are repositories of rich crop germplasm and skilled plant breeding that could offer unique solutions or provide a platform for modern improved technologies with effective pest and disease resistance traits. Use of such germplasm for developing varieties/hybrids with disease or pest resistance both by public and private sector research efforts is the order of the day. However, these could just be simple exchanges; or simple licensing between public and private sector units involving arbitrarily assigned value and not active partnership. A collaboration that not only enhances the value of the material in use, but also brings forth a multitude of benefits to society is a model that needs to be promulgated in emerging economies, especially while utilizing genetic resources. This paper presents three such models of public-private partnerships by Brazil, Chile and USA involving unique approaches of valuing improved genetic material that helped enhance the overall value of the end product and also promoted effective public private partnerships for emulation by other emerging economies.

Keywords: Technology transfer, public private partnership, valuation

Innovative technical knowledge has well been proven to be the source of productivity enhancement in general and of agricultural crop productivity in particular. Public sector universities and research institutions have been the primary sources of such technical knowledge packaged as improved technologies. The effort in technology development is complete only when the technology is adopted by the end user, which is possible only if the technical knowledge is transformed into a product suitable for commercial production and application. It is thus imperative that university/research organizations understand the needs of the industry or work in close collaboration with the industry. With a view to enhance university/research-industry linkages, augmenting 'market driven research' and assign 'value' to innovative research, universities world over have initiated technology transfer and commercialization efforts. The Bayh-Dole Act 1980 (35 U.S.C. 200 et seq.) has particularly been referred to as enabling university/research organizations to surge forward in this endeavour. Evidence from the US universities and research organizations suggests strengthening of university industry linkage post Bay-Dole Act with technology transfer and commercialization efforts, generated a fourfold increase in numbers of licenses and royalty incomes between 1980 and 1990 (refs 1,2). The share of total R&D support to US colleges and universities had risen steadily from 5.3% in 1953, to 10.0% in 1975, to 11.0% in 2000. Of the US$ 42,431 billion in research performed by the US academic sector in 2004, 61.5% was provided by the federal government, 19.3% was from the institutions' own funds, 9.0% provided by private non-profit organizations, and approximately 5% each by industry and special state government programs.[3]

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According to recent estimates by Association of University Technology Managers (AUTM), the US university system's total licence revenue increased by 3% from 2009 to 2010 at US$ 2.4 billion[4] from transfer of innovative technologies and commercialization through university industry linkage in 2010. This revenue is primarily an indicator that technologies developed at universities and research institutions have been incorporated into products. Revenue is generally obtained as a royalty on product sales, so this revenue demonstrates that valuable technology is reaching the public. This only further justifies the argument that 'innovation' is the primary source of technical knowledge as has been emphasized in several fora by the World Intellectual Property Organization's (WIPO's) development agenda[5] and that the true value of an innovative knowlegde is realised when it is commercialized. The new world order under the World Trade Organization (WTO)-led Trade Related Aspects of Intellectual Property Rights (TRIPS) Agreement also has emphasized and compelled emerging economies to adopt intellectual property rights (IPR) legislation for enhancing innovation behaviour among its researchers.

A number of emerging middle and low income economies have been quick to emulate this policy, falling in line with TRIPS, and have started adopting legislation for initiating technology transfer and commercialization of university/ research results since early in the new millennium. Most countries have either initiated the process or have completed modifying their legislation to become TRIPS-compliant and also have started technology transfer offices (TTOs) in their universities and research organizations. Stronger university-industry linkage, boost to 'innovation behaviour' through faster scaling up of 'proof of concept to industrial application', 'incentivizing innovation' in research and enhanced public private partnerships (PPP) are some of the positive outcomes that weigh in favour of promoting the concept of TTOs and commercialization offices at the university/research organizations. The primary aim of TTO and commercialization of university research is to make the research more useful for the industry and also to enhance the participation of the private sector into public sector research endeavours, especially in agricultural research, though such linkages appear common in the pharma and medical devices fields in developed countries.

Public-sector lead universities/research organizations, and national and international seed depositories are repositories of rich and useful germplasm that could offer unique solutions or provide a platform for modern improved technologies with effective pest and disease resistance traits. Use of such germplasm for developing varieties/hybrids with disease or pest resistance both by public and private sector research efforts is the order of the day. However, these solutions could reach the market through simple exchanges; or through simple licensing between public and private sector units involving arbitrarily assigned value and not necessarily involve active partnership. A collaboration that not only enhances the value of the material in use, but also brings forth a multitude of benefits across society is the one that needs to be promulgated in emerging economies, especially while utilizing germplasm/genetic resources.

This paper presents three cases of public private partnership models in agricultural research collaboration involving germplasm valuation from Brazil, Chile and USA. The paper attempts to draw inferences useful for application in emerging economies like India, which are in the process of expanding technology transfer and commercialization to enhance PPP models. The paper is presented in three sections: the first presents two case studies, one each from Brazil and Chile involving PPP on genetic resources; the second details the case study undertaken by the author on Soybean Aphid Management research and PPP model adopted by Michigan State University, USA and the last draws inferences and useful lessons from the three cases for application in other emerging economies.

University/ Research Institute Industry Linkage

Case Study of Brazil's Technology Transfer Efforts

Brazil is one of the earliest among the emerging economies to adopt IPRs and technology transfer policies.[6] Besides the central office for technological innovation established at the National Council for Scientific and Technological Development to promote innovation at universities and encourage technology transfer to Brazilian industry since mid 80s, Technological Innovation Centers operate today at different Brazilian universities to protect intellectual property and facilitate the university–industry interface. Brazilian Agricultural Research Corporation (EMBRAPA) started a special agency, the USP Agency for Innovation, in 1996. The Technology

Development Support Centre started in 1989, and Inova, a TTO under Unicamp in 1999 (ref. 7).

Unicamp's Inova, one of the biggest technology transfer offices in Brazil, undertakes patenting innovations and transfer of technologies. Within a short period of four years since inception, by 2003, Inova obtained 191 patents (48% in chemistry) and had administered over 128 technology transfer agreements.[6] Inova owns the technologies and attempts to commercialize them on its own, though the law permits transfer of ownership to innovators. In a unique model of commercialization, instead of commercializing available technologies arising from basic research programmes after an invention occurs, Inova also undertakes market research for identifying the market demand in advance of the research project and attempts to scale up and commercialize those specific technologies that have proven market demand. Inova also promotes joint research projects with 50% funding from private companies. Over ten companies that have incubated with Inova in the last two years are ready for take-off. The TTO allotted an exclusive licence of one of its agricultural technologies to a company for 20 years with 1.5% royalty per annum, 33% of which is distributed to the innovators.[8]

A unique case of PPP was implemented in soybean research by EMBRAPA during late nineties. EMBRAPA, a publicly held research organization, has been a repository of useful germplasm for several crops including soybean and is a leader in Brazilian soybean variety development since the 1990s,[9] Pharmacia (former Monsanto), a private seed company, bought a small Brazilian soya seed company 'Monsoy' in the early 90s, which had developed varieties of soybean with glyphosate resistance, but were low in productivity. Pharmacia initiated a move to use better-performing EMBRAPA varieties for creation of genetically modified organisms (GMO) glyphosate resistance, which in turn would be marketed by Monsoy. According to the Brazilian Plant Breeders Rights (PBR) law, which follows the 1978 UPOV treaty as amended in 1991, a GMO variety varying from the starting variety only by the presence of the glyphosate-resistance gene insertion would be an 'essentially derived variety'. Thus, if Pharmacia used plant-breeder's-right-protected germplasm/ varieties of EMBRAPA for any genetic transformation, Pharmacia would require a licence to EMBRAPA's plant breeder's right to propagate the GMO variety. In view of the win–win proposal arising from making glyphosate-resistant essentially derived varieties from EMBRAPA germplasm, both Pharmacia and EMBRAPA were interested in executing the licence but were unsure of assigning value for the EMBRAPA owned germplasm. Through the intervention of Cornell University lead economists, this PPP was successfully negotiated and executed.

The results of the 'economic surplus model', which takes into account both the anticipated costs and anticipated accrual of benefits due to adoption of a new technology, adopted by the economists suggested enhanced benefit to both Brazil's economy and the rest of the world if Pharmacia and EMBRAPA cooperated and developed GM varieties. The model predicted the flow of costs and benefits to the two organizations and the world at large with and without the technology. Results suggested that the combined cooperative average annual sales of soybean varieties from Pharmacia/ EMBRAPA resulted in US$ 1070 million additional revenue as against that from the sale of EMBRAPA varieties alone or Pharmacia's varieties alone. Further, the total economic surplus generated from the PPP was estimated at US$ 51.49 million for Brazil alone.[9] Based on these results, EMBRAPA and Pharmacia arrived at the appropriate value for the use of germplasm from EMBRAPA and negotiated the PPP model.

Case Study of Chilean Efforts at Technology Commercialization

In Chile, the National Innovation Council for Competitiveness (Consejo Nacional de Innovación para la Competitividad, CNIC) is the highest body that caters to the needs of research and development, while Foundación Chile – an innovative facility launched in 2004, assumes the primary responsibility of forming university-industry research collaborations for improvised PPPs.[6,8,10]

Chile, a country rich in natural resources, became active in technology transfer and commercialization starting with the new millennium. The CNIC was initiated to provide broad strategies to improve the relevance and quality of the supply of innovative ideas and to encourage the private sector to invest more into the public R&D system. Chile adopted a system of intermediaries who link research and industry information flows referred to as technology transfer and commercialization system. Chile adopted three main complementary approaches in transferring advanced science and technology knowledge into productive use: (i) management of intellectual property; (ii) strategic partnerships for applied oriented research; and (iii) creation of new knowledge based firms.[9] However, due to reasons such as an insufficient and ineffective reward system, preference for publication over commercialization, and no facility for benefit sharing of technology commercialization and royalty sharing, collaborations could not be initiated. Funding sources' preferences for research being institutional or indigenous placed high priority on basic research and not on research of commercial value.[11]

In addition to the TTOs, universities also take help from special units, such as Dirección de Investigaciones Científicas y Tecnológicas de la Pontificia Universidad Católica de Chile (DICTUC), a company set up 70 years ago by the Pontificia Universidad Católica de Chile, to interact with the industry by providing advisory and certification services, training and incubation and spin offs (mainly of campus related activities). Yet, its effectiveness is hampered by several constraints, such as project based financing, absence of IP expertise, etc.[10]

Since 2004, Foundación Chile in collaboration with Corporacion Nacional del Cobre (CODELCO) and Nippon Mining has initiated a biotech research alliance.[11] In a unique approach, Foundación Chile has developed an international network of parties through a R&D consortium, a technology partner, and a local technology transfer organization for scaling up the results of the research collaboration. The products of such collaborative research have been commercialized through new companies with specific commercial foci along the value chain, which included nurseries with access to germplasm, and capacity to undertake some research. After thirteen years of research, one such consortium, the Biofrutales Consortium, developed the first transgenic variety of table grapes in Chile, which have the characteristic of not requiring chemicals to be resistant to the main fungi that attack vines and affect production, such as botrytis and the powdery mildew. Since 2005, Foundación Chile has successfully commercialized over 1000 transgenic lines being tested for disease resistant grapes.[11] To achieve this grape, derived from the Thompson seedless variety, the consortium paid the rights for the US technology that was later perfected in the country in order to have a platform for genetic transformation. It is one of the first such experiences in the world, and the results have been patented as well. It is stated that more than 3,000 million pesos, about US$ 4 million, both from public and private resources, between 2006 and 2011 has been allocated for developing more competitive vine breeding programs (61% of the budget), as well as for nectarines and cherry trees, thus paving way for renewed models of cooperation in scientific pursuits.

Innovative PPP Model of Michigan State University

While the two case studies referred to above bring forth two models of PPP in enhancing the value of a research output through research collaborations, both have been based on specific but well established products or traits involving genetic resources. Further, both the case studies highlight genetic transformations which have well established IPR protection possibilities as well. The valuation of the genetic resources used showcased varied models. This section in contrast presents a case of R&D collaboration and partnership between a public research organization and a quasi-private organization representing the producers themselves in arriving at a solution to a problem benefitting the society as a whole. The PPP approach presented here is unique since it does not include a GMO and is formulated for the generation of products rather than on provision of a finished product and involves the 'crop growers' themselves as primary stakeholders.

PPP Model for Soybean Aphid Management (SAM) from MSU

The US raises more than half of all the soybeans produced worldwide. In 2008, US soybean farmers harvested 2.959 billion bushels (80.54 million metric tons) of soybeans. Soybean is an important crop in Michigan and the Midwestern United States. Farming soybeans has an economic impact of over US$ 1 billion for the state of Michigan, which plants over 2 million acres annually.[12]

Soybean Aphid (SA) is a major invasive pest of soybean in North America. Native to Asia, SA was first detected in the United States in the state of Wisconsin in 2000. SA rapidly spread to over 20 north-central states within four years.[13] Heavy infestation of soybean aphid can reduce yield directly through plant feeding and indirectly through virus transmission and reduction in seed quality.[13,14,] In 2003, when most north-central states suffered from unprecedented soybean aphid infestations, yield losses were estimated to be 0.4 to 0.9 ton/ha (9 to 13 bu/a).[14-17] At US$ 7.00/bu this represented a loss of at least US$ 2.4 billion.[18] The Unites States national average yield fell by 11% compared to the previous 5-year average, and US soybean prices exceeded US$ 294/ton ($ 8/bu), 25% above the previous year.[12]

By 2005, the insecticide treated soybean area in mid-west states including Iowa, Illinois, Indiana, Minnesota, Michigan and Ohio leaped to 20% in 2005, compared to less than 1% before 2000 (ref. 18). Prophylactic treatments with stylet oils or insecticides could protect soybean from yield loss. However, the cost of prophylactic treatment exceeded yield enhancement. Control failures also occurred, depending on the arrival time and pest buildup. Further, most commonly used soybean aphid insecticides (stylet oils, esfenvalerate, lambda-cyhalothrin and zeta-cypermethrin) were found to be moderately toxic to humans.[19,18] Thus, as an alternate to prophylactic seed treatment and early season sprays, an integrated pest management (IPM) protocol for SA was developed based on extensive field testing in the soybean aphid infested states of Iowa, Michigan, Minnesota, Nebraska, North Dakota, and Wisconsin between 2003 and 2005. Researchers identified soybean aphid population growth rates and the relationship between soybean aphid density and yield loss, thereby establishing an action threshold at 250 aphids per plant[19] that warranted action. Insecticide sprays, whether prophylactic or applied as part of IPM, cost farmers approximately US$ 8-12/a in 2004. Under IPM, ineffective spray treatments were avoided, but a cost of between US$ 1.00 and $2.00/a was incurred for scouting.[18] Thus, in years of low SA incidence IPM incurs a cost of only US$ 2.00/a, but when spraying is required IPM would cost approximately US$2.00/a more than prophylaxis.

A study by Song and Swinton[21] estimated the loss from soybean aphid in 2004 to be in the range of US$ 274 to $698 million.[22] If the soybean aphid population exceeds the threshold and is not controlled, it may cause up to 0.66 ton/ha (9.7bu/ac) yield loss. However, by timely treatment when above threshold, using prophylactic or IPM treatments, the yield loss can be averted. Although there is no significant difference in yield effect between IPM and prophylactic treatments,[18] the treatments differ in control costs, which consist of spraying cost, insecticide cost, and scouting costs for IPM. The pest incidence is anticipated to increase in future, causing both yield as well as environmental losses. Efforts have been on to find alternate pathways for SA control including identification of SA resistance by MSU.

The Alternate Approach for SAM

When SA was introduced into the US, no commercial cultivars carried SA resistance. Furthermore, no sources of SA resistance were known in early maturing (maturity group 0 to III) soybean germplasm.[23] This left farmers with insecticides as the only means of controlling SA. The SA is expected to cause yield losses of up to 50% from physical damage and may cause damage through transmission of viruses into the plant. Thus, in the long run, host plant resistance is the preferred solution rather than risk the cost of insecticide spraying, which has the additional negative environmental consequences of killing beneficial insects.

Michigan State University (MSU) developed this alternate approach by introgressing aphid resistance from exotic germplasm to elite Michigan soybean germplasm. To facilitate rapid breeding, DNA markers were developed in 2007. The Michigan Soybean Promotion Committee (MSPC),[23] was created in 1976 to help promote soybean in Michigan. The MSPC is financed through Michigan soybeans sold. When a grower sells his soybeans to a ‘first purchaser’ in Michigan, the ‘first purchaser’ collects one-half of one per cent (0.5%) of the value of the soybeans sold. The collected amounts are referred to as ‘checkoff’ fees. The checkoff is then equally divided between MSPC and the United Soybean Board. The Michigan portion is primarily divided among advancing soybean marketing, improving production technology, development of new uses for soybeans, and communications to producers by MSPC every year. MSPC often partners with researchers at Michigan State University.

A total of around US$ 200,000-300,000 is expended every year by MSPC at MSU towards soybean improvement, soybean agronomy, and alternative use programmes.[24] Michigan State University’s research efforts at developing elite germplasm for SAM have been funded by MSPC. In view of the potential of the new technology, MSPC came forward to license the technology from MSU through its Technology Transfer and Commercialization office, MSU Technologies (MSUT). The Michigan Soybean Promotion Committee further decided to commercialize the invention to ensure its availability to all the soybean growers by sublicensing it to a mediator seed genetics company. This mediator company specialized in the introduction of unique and advantageous trait genes into the commercial market, and was expected to ensure that the invention is sub-licensed to a number of seed companies for further testing and introducing the gene into other soybean varieties. A number of commercial seed companies have sublicensed the invention for further testing and to be brought out as soybean aphid resistance (SAR) system. The product is likely to reach the market by 2016.

The Michigan State University is prosecuting patents in the United States claiming the rag3, rag4, and rag6 loci.[25] The University is also seeking to trademark its SA resistance traits under the SPARTA™ name.[26] Seeing the potential of the identified elite germplasm, the marker and the gene, MSU has obtained a patent on the invention at the request of MSPC. The Michigan Soybean Promotion Committee and MSU entered into a licence for the technology under which they share the royalties generated from MSPC's sub-licensees.

Economic Impact of Elite Germplasm of Soybean

When the SA resistance invention reaches the market, it is likely to result in enormous economic benefits to all stakeholders of soybean production. In order to provide the economic evaluation of this technology, four alternate valuation scenarios have been considered, based on the review of literature. These include, the estimated economic loss due to soybean aphids, (i) if left uncontrolled, (ii) taking up prophylactic control, (iii) gradual adoption of active threshold-based IPM and (iv) the use of elite aphid resistant germplasm. Results based on literature review suggest the SA, if left uncontrolled, would have an estimated cost US$ 7.16 billion (the present value of economic loss for the period 2000-17), or 3% of the total US soybean production value during that period. Prophylactic control can protect yield loss caused by soybean aphid, but it increases control costs compared to the uncontrolled scenario, reducing the estimated loss from US$ 7.16 to $ 3.33 billion, the remaining loss being the cost of prophylactic control.

Further, assuming that the IPM is adopted gradually, thereby replacing prophylactic control between 2004 and 2017, additional control-cost losses can be avoided, lowering SA control losses to US$ 1.34 billion. Based on the direct research and extension costs of US$ 31 million, the internal rate of return to investment in active threshold-based IPM for soybean aphid control is 140% (attributed exclusively to the direct costs of research and outreach) (Fig. 1).

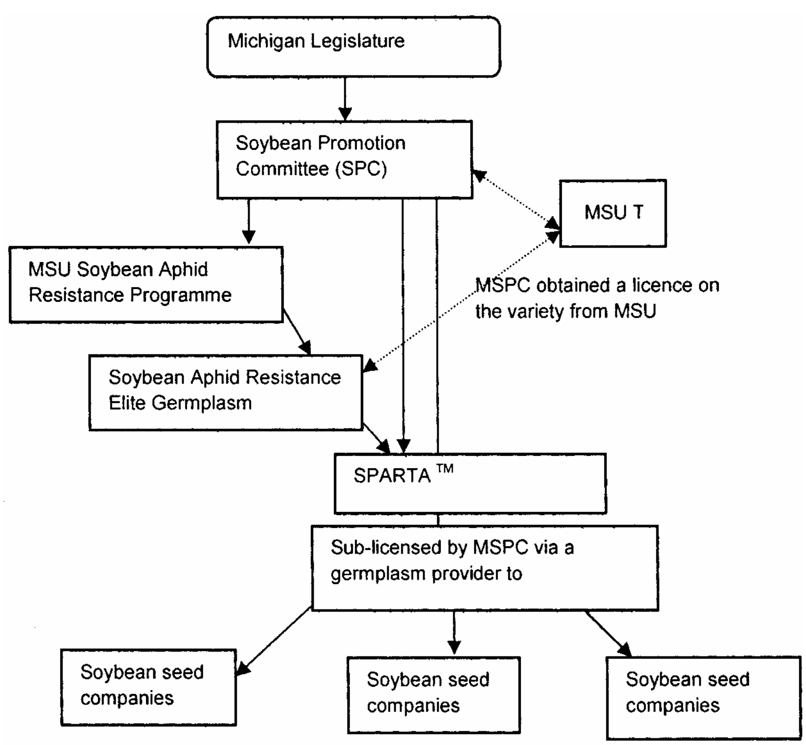

Fig. 1—PPP model for SAR

The new varieties that would reach the market by 2016 with Sparta soybean aphid resistance would change the entire SAM scenario. Despite the increased cost of seed due to the inbred resistance at US$ 3/acre, if resistance is total then the SA resistance trait technology would completely eliminate the cost of insecticide treatments and thereby result in enhanced economic benefit to the soybean growers and society at large through decrease total soybean prices. Not considering the beneficial environmental effects, the new technology is estimated to avert the estimated loss of over US$ 7.16 billion without incurring any insecticide costs (Table 1).

In an attempt to demonstrate the benefits of a PPP, Table 2 presents estimated potential royalty returns on SBA resistance to different stakeholders. Even with an arbitrary value of US$ 0.0025/# of seed chosen as the technology royalty and a planting rate of about 1 bu/acre, it accounts to US$ 0.125/acre planted. Assuming a rate of 58% aphid infestation (the percentage of US soybean acreage infested as per USDA data) and 15% market penetration, the royalties accruable to MSU's SA resistance is US$ 3.6 million dollars. The royalties will be split 50/50 with MSPC per the license agreement between the parties. Under this model, MSU may earn about US$ 1.8 million in royalties from its SA resistance traits over the lifetime of the SA resistance patents.

According to the above calculation relating to Table 1, the market should be willing to pay US$ 3.00/bu for SA resistance traits. Typically, trait gene values are divided between the trait provider and the trait user-farmer such that the farmer accrues economic benefits from purchase of the trait technology. Assuming a 50/50 split leads to a trait royalty of US$ 1.50 to the technology provider. Alternatively, the technology provider typically receives somewhere around 25% of the market value of its technology (or, more precisely, the operating profit from use of the technology), the remaining 75% is retained by the licensee as per the oft-quoted 25% 'rule of thumb' for setting royalty rates.[27] Using the rule of thumb, MSPC, the licensee in this case, could reasonably expect to receive a royalty of US$ 0.75/bu. These two benefit-apportionment models place the reasonable royalty rate at between US$ 0.75 and $1.50/bu. This again demonstrates that the royalty of US$ 0.125/bu used above is likely very conservative.

Table 1—Economic evaluation of different pathways of SAM in Central USA

Scenario	Unit cost ($/ha)	Aggregate cost (US$ billion)	Aggregate loss (US$ billion)
Scenario I (Uncontrolled SA)			
Yield and total economic loss	0.66t		7.16
Scenario II (Prophylactic)			
Cost of spraying	8.00		
Cost of insecticide	17.40		
Sub-total77451000 Ha	25.45	1.97	3.33
Scenario III (IPM)			
Aggregate loss			1.99
Direct IPM cost	24.95		
Scouting costs	5.00		
Sub-total	29.95	2.32	
Research Cost		0.31	
Net estimated benefit			0.569 – 1.257
Internal Rate of Return (IRR)			140%
Scenario IV (Genetic resistance)			
Apportioned additional cost of seed (US$)	7.5		
Net benefit accrued			6.7

Source: Author compilation based on refs 18 & 20 and own data

Table 2—Scheme of estimates for royalty accruals for SAM resistance

Particulars	Units	Value
Base level production (2003)	76.6 Million MT	
Seed requirement (lbs)	1# planted/50# harvested (0.02)	3377447200
Purchased seed (lbs)	0.75	2533085400
Aphid R market estimation (lbs)	0.58	1469189532
Expected market penetration (%)		
During 2021-2024	0.15	220378430
Total sold (lbs)		2233168000
Royalty rate/Unit of seed (US$)	0.0025	
Total annual royalty (US$)		5582920
Annual royalty receivable by MSU (US$)	0.5	2791460

Source: Author compilation based on proposed payment rates by MSUT

Conclusion and Policy Inferences

Technology transfer and commercialization efforts need to ensure that the innovations from university research reach the industry quickly and also get scaled up and sold as products, thereby benefiting society at large. Further, TTOs are anticipated to strengthen the linkages between university research and industry. One of the issues that need focus by the technology transfer efforts is the 'pricing' or 'valuation' of technologies. A second issue is enhancing public-private partnerships, especially in emerging economies like India. Although a number of technologies in the form of varieties/hybrids and elite germplasm are exchanged between universities/research organizations and industry, it involves a simple exchange or a process of licensing involving an upfront payment and a minimal royalty. The value or the price for these materials is arrived at arbitrarily. As a number of TTOs under the Indian Council of Agricultural Research (ICAR) system are debating the valuation processes and approaches, this paper brings together three case studies that not only provides successful partnerships between university/research organizations and industry, but also paves the path for assigning value for the contributions of university/research efforts at collecting and conserving unique or elite germplasm.

While it is a usual practice for the private companies to utilize the output of research from the university to further the research efforts for private commercial gain and to benefit the society, it is the time, type and terms of partnership that needs assessment. The three cases presented in this paper bring forth the following specific points for consideration while entering into PPP and also while valuing the genetic resources or products for use by the industry.

(i) Public private partnership involving technologies often tend to be based on the products already developed from basic research without input from industrial partners. While assigning value for the product or a specific trait, both parties involved tend to take the 'actual costs involved approach' and seldom consider the 'potential economic benefit' accruable to the society due to the technology/ product adoption. The true value of an innovation or a genetic trait depends on the total economic value society would have lost without the technology, as has been demonstrated by the valuation of soybean varieties by Brazil.

(ii) The PPP model of Chile is suggestive of the role of facilitators in effective functioning of a PPP. Further, if the product/genetic resource in question are 'protected' through IPRs, the valuation process gets even more streamlined. Therefore there is a need for the researchers to aim towards development of technology/advanced lines that hold definite intellectual property rights and they are protected as well.

(iii) There is a need to create awareness and imbibe the process of 'assigning a value' to the results of R&D by both the public and private sector players. A PPP is one that involves collaboration at different stages. Involving a private-sector partner right from the start of the research initiatives through active funding support by the parties involved would improve the commercial potential of project outputs and hence help realize true value and additional benefits. Adopting a crop specific 'consortia' or 'joint venture' research could be viable alternatives.

(iv) Creating 'crop specific councils' involving growers and other stakeholders is an assured way of ensuring active involvement of all the stakeholders in crop-based R&D efforts. The Michigan model of SAM brings forth the fact that involving the crop growers through research priority setting and through the process of arriving at research solutions needs to be adopted by other emerging economies as well. The private sector would then be able to not only appreciate the true value of the germplasm or genetic material used, but would be willing to share royalties with the research institutions.

A number of emerging economies face similar conditions wherein the public university/research organizations hold unique germplasm that could add immense value in furthering research efforts. Linking with the industry through PPPs meets the objective of using the germplasm for useful purposes, benefiting the society as also strengthening the research capabilities of the researchers through benefit sharing. Assigning value to the contribution of germplasm or specific trait needs special attention.

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