Technology Development and Transfer in Agriculture

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Abstract

Technology development is a response of scientific knowledge to the changing needs of consumers, farmers, community, country, and world trade. In the late 1960s and early 1970s there was a need to increase total production by intensive agriculture. However, in the 1990s, the emphasis has shifted towards technology development that considers farmers' needs, uses indigenous technology to complement scientific developments, and gives due consideration to sustainability of natural resources and other environmental concerns. Technology development and transfer are dynamic, and the success of a new technology is determined by its adaptability to, and its adoption by, the client groups. It requires a good research and extension infrastructure, congenial policies, and market for the commodities. Improved technologies need not be innovations, but could be reallocations of resources, and realignments of components of existing practices to match the needs of farmers and agro-socioeconomic conditions. Involving farmers in identification and prioritization of production constraints, and in planning and managing on-farm research trials is necessary to focus on target groups' requirements. ICRISAT's experience and role in technology transfer involving national programs, with particular reference to Legumes On-farm Testing and Nurseries (LEGOFTEN) and Asian Grain Legumes On-farm Research (AGLOR) programs are discussed in the paper.

技术开发是科学知识对消费者、农民、社会、国家和世界贸易不断变化的需求所作出的一种反应．六十年代末至七十年代初要求通过精耕细作的方式增加总产，但到了九十年代，重心已经转移到将农民的需求考虑在内，将科学的进展与当地技术融为一体，并对自然资源的可持续性和其它环境问题给予应有重视的技术开发上来．

技术开发与推广是动态的，一项新技术成功与否取决于其适应性以及用户对它的接受程度．它需要良好的研究与推广体系，适宜的政策及其商品的市场．优良的技术未必是革命性的，但应当对资源重新分配，对现有各种措施重新组合以期满足农民和农业社会经济状况的要求．要重视服务对象群体的要求，应当让农民参与鉴定生产制约因素，确定应首先解决哪些问题，并参与田间试验计划的制定与管理．

本文对国际半干旱所在国家项目特别是在豆类大田测试和繁育(LEGOFTEN) 以及亚洲食用豆类田间研究(AGLOR) 项目技术推广中的经验与作用作了讨论．

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Introduction

Agriculture started with the domestication of useful plants and with this began the process of technology development. What we call today 'traditional agriculture' is the accumulation of farmers' knowledge and experiences over many generations. Traditional agriculture' was dynamic and ever evolving, but also in harmony with nature and the farmer. However, increasing human population pressure and the industrial requirements of agricultural raw materials have distorted this equilibrium and the need for new knowledge and technology has increased greatly. Many technologies have evolved but the equilibrium with nature has never been restored. Incalculable harm has been done to agricultural systems, so often because of overexploitation. Recent concerns have added new dimensions to the technology development and transfer process. Efforts are now being directed towards achieving a new equilibrium with nature while making agriculture self-sustainable and increasingly productive.

Technology

Scientific knowledge, when put to routine use for the benefit of mankind, is called technology. Any new technology to find acceptance must be competitive in today's and tomorrow's environments, and bring about economic benefits at all levels of a society while maintaining eco-friendliness, self-sustainability of the system, and social and cultural compatibility.

Technology Development

Technology development is an on-going response of scientific knowledge to changing requirements of society. It focuses on a target group keeping in mind the resource base, socio-cultural factors, and government policies to exploit the available opportunities and match scientific knowledge with requirements.

A good development process should be flexible and offer options to the target group for successful adaptation and adoption of any new technology. Generation of new scientific knowledge is essential to upgrade the existing technology, so a strong and well-focused research program is a prerequisite for any technology development. This research program may involve both on-station and off-station research which complement each other and help in developing the most appropriate technology Developments in scientific knowledge do not necessarily address social, cultural, and economic issues so it is left to the technology development process (putting scientific knowledge to practical use by the society) to address these issues and improve the quality of life and the environment. Verification of the technology in the targeted system is an important part of the technology development process.

In the current agricultural context, the development of a new technology involves increasing productivity at the farm level in an eco-friendly and sustainable manner. A simplistic approach is to first identify those constraints that affect production at the farm level, and to devise appropriate solutions to overcome them. The role of farmers and extensionists in this process is crucial. Their involvement helps in maintaining the focus and relevance of the technology to the real farm situation. The role of individual components of technology and their synergism leading to a full package should be highlighted to farmers in an understandable way so that they can make their choice.

Instead of aiming for green revolutions which will be difficult to implement in rainfed resource-poor agricultural areas, a step-wise progression in upgrading technology may be more appropriate to achieve sustainable agriculture. A full package of technology, though more beneficial, may not find wide acceptance. Farmers will choose the whole package, or selected components of the technology, depending on their perception of the benefits. For sustainable development, a balance has to be struck between the short-term and long-term gains, and awareness of the long-term gains will have to be created through education. Costs of community actions and also of individual actions leading to community benefit will have to be borne by the community or government.

Technology Transfer

An effective technology transfer system requires a carefully thought out plan, clearly communicable ideas, and a cooperative effort. It should be capable of dealing with a wide spectrum of ground realities. In each situation, the fundamentals of the process remain the same, only operational considerations and implications vary. Technologies compatible with felt needs, economic and socio-cultural factors, and government policies are amenable to effective transfer.

Partners in Technology Development and Transfer

Agriculture in the developed world is fast advancing and the adoption of technology occurs at a rapid rate. However, in many developing countries, agriculture is yet to be influenced by the rapid change and progress of science and technology in many areas. A few 'revolutions' have occurred in developing world agriculture, but they largely remain confined to assured irrigated areas and capital-intensive production systems.

Over the past 40 years, various reasons have been given for the failure of resource-poor farmers to adopt new technology. In the late 1980s and early 1990s, it was realized that the available technology did not match the goals of resource-poor farmers because they did not participate in planning and evaluation of technology (Chambers et al. 1989). The current emphasis, therefore, is on farmers' participation in the process of technology development and adaptation. The farmer is better equipped to give appropriate input to the process of technology development, adaptation, and transfer as he or she is the only integrator of all factors (scientific, economic and social) at the farm level.

The need for innovation and change should originate from farmers. Imposed change will not be long-lasting. Extension workers and researchers can only help farmers to articulate their demand for innovation. Researchers should offer a choice of technology options and realize that technology based on and using indigenous know and resources is likely to be more appealing to farmers. Both farmers and extension workers can help the researcher in understanding indigenous knowledge. Involvement of both farmers and extension workers in the complete process of technology development is essential if one is to gain their confidence and acceptance of the technology As success of a technology is judged by its adoption, the farmer is the ultimate judge.

Experiences with Technology Transfer in Agriculture

Legumes On-farm Testing Nurseries (LEGOFTEN) in India

Edible oil imports into India during the 1981-86 period rose to US$2 billion per year. The Government of India launched a Technology Mission on Oilseeds' in 1986 to increase indigenous production of oilseeds and make the country self-sufficient in the edible oil sector. ICRISAT was invited by the government to help in testing, adapting, and disseminating improved groundnut production technologies in collaboration with the national research and extension programs in India. The LEGOFTEN Unit at ICRISAT Asia Center was created in 1987 in response to this request from the government (ICRISAT 1993). An initial joint-planning meeting was held to assess the production technologies used by farmers and to formulate an improved technology package with local variation for testing in different agroclimates (Table 1).

Selected extension staff and managers of seed farms participated in an orientation-cum-training course on the conduct of on-farm trials and the use of various components of improved technology before initiating on-farm trials. Although the first year's verification trials were conducted on seed farms, the subsequent testing was on-farm involving farmers.

The on-farm trials had four treatments at each location and each treatment covered 0*2 ha.

T_1: Improved cultural practices + improved variety (Improved technology).

T_2: Improved cultural practices + local variety.

T_3: Local cultural practices + improved variety.

T_4: Local cultural practices + local variety (Farmers' practice).

During 1987-90, 141 trials (83 in rainy seasons and 58 in postrainy seasons) were conducted. The improved cultural practices gave 20.2% more pod yield and improved varieties gave 263% more pod yield over local cultural practices and local varieties (Table 2). The improved technology (improved cultural practices + improved varieties) gave, on average, 61% more pod yield than farmers' practice (existing cultural practices + traditional varieties), showing the synergistic effect of improved cultural practices and

Table 1. Improved and local groundnut production technologies[1] for on-farm trials/demonstrations, India.

Field operation/input	Improved package	Local package (general)
Land preparation	Plowing, clod crushing, and harrowing to obtain a fine tilth	Deep plowing once, light plowing twice, harrowing twice
Basal fertilizers (ha"[1])	FYM[1] = 10 t Ammonium sulphate = 100 kg SSP = 300-400 kg MOP[1] = 0-80 kg $ZnSO_4$[1] = 10-20 kg (once in 3 years)	FYM = 5-12 t DAP = 100 kg MOP = 100 kg $ZnSO_4$ = 20 kg
Sowing date	Jun with monsoon (rainy season)/Nov (postrainy season)	Jun/Nov, Dec
Seedbed	Broadbed[1] (or narrow bed)	Flat
Variety	ICGSs 11,21,37,44,65,76, ICG(FDRS) 4 or ICG(FDRS) 10	TMV 2, TMV 7, JL 24, SB XI, Co 2, S 206, KRG 1, GG 2, VRI 2, AK 12-24
Seed rate (ha^{-1})	120-125 kg	125-150 kg
Spacing	30 x 10 cm	30 x 10 or 45 x 10 cm
Weed control	Stomp®[1] 30 EC 3.0-3.5 L ha^{-1} (or hand weeding)	Hand weeding
Seed dressing (kg^{-1} seed)	Thiram[1], Bavistin® or Dithane M 45® @ 2-3 g	Thiram @ 2g
Sowing method	Dibbling[1]/drilling	Behind plow/drilling
Gypsum (ha^{-1})	400 kg at flowering	200 kg at flowering

Continued......

Table 1. ***Continued....***

Field operation/input	Improved package	Local package (general)
Plant protection	Bavistin®[1] 50 WP 250 g + Dithane[1] M 45® or chlorothalonil (Kavach®) 75 WP 1 kg ha^{-1} for leaf spots and rust, as required Dimethoate 30 EC 660 mL ha^{-1} for thrips, jassids, and leaf miner Monocrotophos 36 EC 1 L ha^{-1} or Endosulfan 35 EC 2 L ha^{-1} for *Spodoptera* and *Helicoverpa*	Need based
Nutrients	1-2 sprays of $FeSO_4$[1], 2.5 kg + 5 kg ha^{-1} urea, 30 and 45 days after emergence (In black soils where plants show yellowing)	
Irrigation	Sprinkler[1] (or furrow)	Flooding
Harvest	With 65-70% pod maturity	With maturity

1. The above practices in the improved package were compulsory for on-farm trials in the first year. Later on, with increased knowledge and experience, several of the practices were made optional and alternatives were suggested.

(Source: Legumes On-farm and Nursery Unit (LEGOFTEN). A brief report of work. January 1987 - January 1991. ICRISAT, unpublished report).

Although the recommended improved cultural practices were rigid in the first year, to assess their full potential, they were modified/improved upon based on the feedback from extension staff and farmers, and backup on-station trials. The backup trials involved studies on benefits due to land preparation and land configurations, fertilizer use, irrigation systems, pest management, and appropriate cropping systems. Farmers themselves experimented and modified a few components. For example, the width of the broadbed was reduced from 1.5 m to 0.75 m so that furrow irrigation could be effective in red lateritic soils. Similarly,

Table 2. Economic analysis of groundnut production following improved and local cultural practices and varieties in India, 1987-90.

	Pod yield mean (t ha^{-1})			
	Improved cultural practices		Local cultural practices	
No. of Trials	Improved variety	Local variety	Improved variety	Local variety
Rainy season 83	1.96	1.47	1.53	1.21
Postrainy season 58	2.87	2.13	2.26	1.79
Yield benefit				
(over farmers' practices)[1]				
			Rainy season	Postrainy season
Improved cultural practices (%)			21.5	19.0
Improved variety (%)			26.4	26.2
Improved cultural practices + improved variety (%)			62.0	60.3
Extra cost and benefit of improved technology[2]				
Extra production cost (Rs. ha^{-1})			1590 (6220)3	1420 (6990)
Extra net benefit (Rs. ha^{-1})			4410 (3460)	7220 (7330)

1. Farmers' practices = Local cultural practices + Local varieties.
2. Improved technology = Improved cultural practices + Improved varieties.
3. Normal cost or benefit following farmers' practices; average selling price of groundnut pods for seven seasons was Rs. 8000 t^{-1}

(Source: Legumes On-farm and Nursery Unit (LEGOFTEN). A brief report of work. January 1987 - January 1991. ICRISAT, unpublished report).

farmers developed a few implements to make broadbeds, seed drills, diggers, etc. Such active participation and involvement of the farmers enriched the on-farm research process.

Another salient feature of the LEGOFTEN Project was the involvement of the National Dairy Development Board (NDDB), Anand, India, with its well-established network of State Cooperative Oilseed Growers' Federations (SCOGF) to help farmers in production, distribution, and marketing of oilseeds. The joint effort of NDDB and ICRISAT was instrumental in transferring improved groundnut production technology to farmers through the SCOGFs. Now India has almost achieved self-sufficiency in the edible oilseeds sector with groundnut, among other oilseed crops, making a significant contribution to this achievement.

Asian Grain Legumes On-farm Research (AGLOR) in South and Southeast Asia

The success of LEGOFTEN in India prompted other Asian countries to undertake similar projects in collaboration with ICRISAT. The FAO/RAS/89/040 project approved funding for AGLOR Projects to be undertaken in Indonesia, Nepal, Sri Lanka, and Vietnam in 1989. Meetings were held in each of the project countries to review and document the available technology and decide on the target areas for research. Diagnostic surveys using rapid rural appraisal were conducted in each target area (at least two areas representing diverse cropping systems) to identify and prioritize farmer-perceived constraints (Gowda et al. 1993). They were grouped into socioeconomic, biotic, and abiotic constraints.

The joint team of NARS and ICRISAT scientists prepared plans for experiments to address and alleviate the identified biotic and abiotic constraints. Suggestions were made to concerned administrative departments and governments to address the socioeconomic constraints. The on-farm experiments were planned keeping in mind the resource base of farmers, the local availability of required inputs, and the existing/available production technology in the country. Backup and supportive on-station research was also planned to find appropriate solutions to some of the problems before embarking on on-farm experiments.

The on-farm experiments varied across the project countries. For example, in Indonesia (Saleh et al. 1993), the scientists had sets of improved technology that could be tested directly on farmers' fields (Table 3). On the other hand, in Nepal (Sharma and Koirala 1993), the team decided to evaluate single factors (plus and minus) in diagnostic experiments to evaluate and demonstrate the effect of individual technology options (Table 4). Individual components that were beneficial (in increasing pod yield) were combined and tested as a set of technology options in later years.

In Indonesia, both low-input and high-input packages of improved technologies were compared with farmers' practices during 1991 and 92 (Saleh et al. 1993). Although the high-input technology gave higher yields than low-input and farmers' practices, the farmers preferred the low-input technology as it was more economical. Therefore, the low-input technology (as improved practices) was tested on a large scale (21 ha involving 72 farmers) during 1993 in Subang district, west Java, The improved practices gave 1.72 t pods ha^{-1} compared with 1.30 t ha^{-1} of farmers' practice. In a similar large scale (25 ha involving 89 farmers) adoption study in Tuban district, east Java, the improved practices gave 1.81 t pods ha^{-1} compared with 1.05 t ha^{-1} in farmers' practices. These improved technologies are now being extended to other areas in Tuban and Subang districts.

In Nepal, and Sri Lanka, groundnut is considered a low-input crop by the farmers (Sharma and Koirala 1993, Jayawardena et al. 1993). Therefore, careful consideration was given to low-cost inputs such as improved cultivars, fungicidal seed dressing, rhizobial inoculation, and land preparation (tillage). Although the

Table 3. Improved groundnut production technology for evaluation on farmers' fields in Indonesia.

		Improved Technology	
	Farmers'	Level of input	
Input	Practices	Low	High
1. Ullage	+	+	+
2. Broadbeds[1]	-	+	+
3. Sowing with plow	+	-	-
- irregular spacing			
- regular spacing	+	-	+
4. Fertilizers			
a. (kg ha^{-1})	-	25	50
-Urea			
- TSP	-	50	100
- KC1	-	50	100
- Manure	-	2000	5000
b. Micronutrients spray	*	-	+
5. Weeding	lx	2x	2x
6. Pest control	-	-	Need based, supervised
7. Disease control	lx	2x	Need based, supervised
8. Plant population (ha^{-1})	175,000	250,000	250,000
9. Seed treatment	-	+	+
10. Variety	Kelinci/Local	Kelinci/Local	Kelinci/Local

1. = Broadbeds 1.5 - 2.0 m wide accommodating 4 or 6 rows each.
(Source: Saleh et al. 1993).

initial set of improved practices in Nepal had a whole range of inputs, it was later realized that two sets of technology - a low-input and a high-input - were needed for different groups of farmers. In Sri Lanka, although the major groundnut area is cultivated as a rainfed, low-input crop, there was need for developing a high-input technology option for the confectionery groundnut varieties in irrigated areas.

In southern Vietnam the diagnostic survey team found that the farmers were already getting high yields (around 3 t ha^{-1} for a 90-day crop). Under such circumstances/there was limited scope to increase yield levels. Therefore, the emphasis was on reallocation of resources and reducing the cost of cultivation (Dan et al. 1993). For example, farmers usually sow 2 seeds $hill^{-1}$. Diagnostic trials indicated that there were no yield differences between 1 or 2 seeds $hill^{-1}$. On the contrary, one seed $hill^{-1}$ at 15 x 15 cm spacing gave 11% more yield than 2 seeds

Table 4. List of single factor diagnostic treatments for groundnut on-farm research in Nepal.

Purpose/Factors	Treatment[1]
Effect on pod yield of:	
• Seed dressing fungicides	Thiram + Vitavax® (carboxin) (50:50) 3g kg[4] (just before sowing)
• Seed dressing insecticide	Chloropyriphos (12.5 ml kg-[1] seed)
• Rhizobial inoculation	Rhizobial inoculation (NC 92)
• Foliar diseases control	Daconil® (chlorothalonil) 50-60 days after sowing or when around 10 spots plant[1] appear
• Insect pests control	Folithan/Sumithion® 0.5% at 40 days or when insects appear
• Micronutrient spray	Swarnafal® (micronutrient mixture) spray, 30 days after sowing
• Seed rate (plant population)	60 kg ha^{-1}; 40 x 20 cm spacing
• Gypsum	400 kg ha^{-1} at peak of flowering with second weeding. Placed near the base of plant on both sides of a row

1. These treatments were compared with appropriate controls.
(Source: Sharma and Koirala 1993)

$hill^{-1}$ at 20 x 20 cm. Thus, farmers could reduce the seed cost (which is comparatively high in groundnut) by about 50%, and increase profits by adopting 15 x 15 cm spacing. Rhizobial inoculation in post-rice groundnut cropping systems gave 12 to 112% increase in pod yield. Split application of lime (at sowing and at flowering) was also found to increase pod yields by up to 10% compared with a single application at sowing. These low-cost input changes, and resource reallocations have been tested across many farmers' fields and the farmers are adopting them.

Conclusions

In the case studies described above, the technology development and adoption were effective because of:

- Perceivedneedofthefarmerforthetechnologytoincreaseproduction;
- Political will and support by research and extension staff in the country;
- Involvementoffarmersinconstraintidentification;
- Availability of technology locally or regionally for adaptive testing to alleviate identified

- Cooperation and interaction among scientists, extension staff, and farmers; and
- Individual components and technology being amenable for adaptation and adoption by formers.

References

Chambers, R., Pacey, A., and Thrupp, L. A. 1989. Farmers first: farmer innovations and agricultural research. London, UK: Intermediate Technology Publications Ltd., 218 pp.

Dan, N. T., Bien, P. V., Hong, N. X., Lai, T. V., and Lieu, P. 1993. Case studies in on-farm research - Vietnam. Pages 74-82 *in* proceedings of the Regional Workshop on On-farm Adaptive Research, 18-20 Feb 1993, Ho Chi Mirth City, Vietnam (Gowda, C.L.L., van Santen, C.E., Johansen, C., and Nigam, S.N. eds.). Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Gowda, C. L. L., Nigam, S. N., Faris, D. G., and McDonald, D. 1993. On-farm research: planning and implementation. Pages 15-20 *in* proceedings of the Regional Workshop on On-farm Adaptive Research, 18-20 Feb 1993, Ho Chi Minh City, Vietnam (Gowda, C.L.L., van Santen, C.E., Johansen, G, and Nigam, S.N. eds.). Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

ICRISAT, 1993. On-farm research on groundnut, pigeonpea, chickpea, and transfer of technology to semi-arid tropics farmers in India. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics. (Limited distribution).

Jayawardena, S. N., Parthipan, S., Joseph, K. D. S. M., and Jayamanne, P. B. 1993. Case studies in on-farm research - Sri Lanka. Pages 67-73 *in* proceedings of the Regional Workshop on On-farm Adaptive Research, 18-20 Feb 1993, Ho Chi Minh City, Vietnam (Gowda, C.L.L., van Santen, C.E., Johansen, C., and Nigam, S.N. eds.). Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Saleh, N., Adisarwanto, T., Arsyad, D. M., and Sumarno. 1993. Case studies in on-farm research - Indonesia. Pages 43-52 *in* proceedings of the Regional Workshop on On-farm Adaptive Research, 18-20 Feb 1993, Ho Chi Minh City, Vietnam (Gowda, C.L.L., van Santen, C.E., Johansen, C., and Nigam, S.N. eds.). Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Sharma, B. P. and Koirala, G. P. 1993. Case studies in on-farm research - Nepal. Pages 43-52 *in* proceedings of the Regional Workshop on On-farm Adaptive Research, 18-20 Feb 1993, Ho Chi Minh City, Vietnam (Gowda, C.L.L., van Santen, C.E., Johansen, C., and Nigam, S.N. eds.). Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.