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MANAGING AN AGRICULTURAL RESEARCH PROGRAMME FOR POVERTY ALLEVIATION IN DEVELOPING COUNTRIES: AN INSTITUTE WITHOUT WALLS

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SUMMARY

There is no one widely accepted method of managing international agricultural research and numerous different models exist. Here we review one in particular, referred to as the 'institute without walls', from the perspective of the UK Department for International Development's (DFID) Renewable Natural Resource (RNR) Research Strategy (1990–2006). We begin with a brief history of the RNR Research Strategy from 1990 to 2004. We then draw on nearly 15 years experience of managing one of the programmes within the RNR Research Strategy to assess critically the impact of externally and internally imposed organizational and management changes on the performance of the DFID Plant Sciences Programme (PSP). The current RNR Research Strategy (1995–2006), with its emphasis on demand-led research, has greatly increased the relevance and effectiveness of DFID's natural resources research. A comparison between the PSP in 2004 and the early 1990s inevitably concludes that the programme has been transformed: unlike in 1991, research is now firmly demand-driven, much is based in developing countries and farmers are benefiting from the research. Over time, the outputs of the long-term strategic research have been applied in practical plant breeding and participatory crop improvement programmes. Key to the success of the PSP has been the provision of continuous, long-term funding which has allowed projects time to develop and produce outputs of real value to end users. Alongside this, the ability of the PSP to build long-term, in-country partnerships has ensured the effective adoption of its research outputs. We conclude that the successes of the PSP have largely derived from (i) identification of research that is clearly demand driven, (ii) continuous long-term funding that has allowed research to move from the strategic to adaptive phase, (iii) continuity of management, and (iv) the flexibility to develop a wide range of partnerships, both in-country and overseas, based on their ability to deliver.

INTRODUCTION

The positive impact of agricultural growth on poverty reduction and food security has been widely demonstrated, with a major component of this growth driven by investment in agricultural research (Evenson, 2001; Evenson and Gollin, 2003; Pinstrup-Anderson, 2001). High rates of return are commonly achieved from agricultural research and development, and whilst values cited in the literature are wide ranging, a comprehensive statistical analysis undertaken by the International Food Policy Research Institute (IFPRI) of over 300 publications indicates an average return of around 60 % per year for research in developing countries (Alston *et al.*, 2000). In spite of this, however, investment in agricultural research has declined since

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the mid-1980s (Pardey and Beintema, 2001) and discussions still abound concerning how best to organize and manage international agricultural research.

One model involves the funding of research programmes managed from the donor country, but targeted at developing country agriculture. Often, these programmes are managed by a single institute or a consortium of a few institutes that commission research involving many more institutes, within both the donor and target countries. This is the model – 'an institute without walls' – that we review here, and more specifically the Renewable Natural Resource (RNR) Research Strategy of the UK Department for International Development (DFID). We discuss in detail one of the programmes within this strategy, the Plant Sciences Research Programme (PSP), and more specifically, from the viewpoint of demand-led research, how it has helped the programme to be managed to maximize impact and poverty reduction. We describe, with examples, how the programme has produced both international and national public goods of benefit to the livelihoods of farming households and consumers in developing countries.

DFID'S RNR RESEARCH STRATEGY

The first RNR Research Strategy (1990–1995)

The Department for International Development, formerly the Overseas Development Administration (ODA), is the government department responsible for administering the UK's official development assistance. The UK has a long tradition of funding tropical agricultural research, with its roots in the colonial era, and subsequently through the funding of a number of research establishments. Continuing this tradition, the UK government established the RNR Research Strategy in 1990 within the Natural Resources Division (NRD) of what was then the ODA. The strategy defined DFID's priorities for research on renewable natural resources for the next 10 years and was implemented through activities commissioned by initially 16 research programmes (Table 1). Prior to the establishment of the RNR Research Strategy, all DFID research had been conducted by programmes managed in-house or by institutes it funded directly. After 1990, however, the management of research programmes was contracted out to UK universities and research institutes by open competitive tendering (Table 1), with only a few programmes continuing to be directly managed by DFID staff.

In the early RNR Research Strategy, the balance between the programmes reflected prior research expenditure allocations that had emerged from the historic research investment by the UK. Programme activities were very generally defined in terms of subject area while each research programme had its own set of allocations to the commodity groups, e.g. cereals, roots and tubers. The allocation was not based on a formal analysis but was made by DFID staff according to their knowledge of the economic importance of the commodity group, researchable constraints and the strength of existing UK scientific capacity to address these constraints.

The research programmes were externally monitored and, as early as 1992, questions were raised within DFID concerning the extent of the impact of the research

Table 1. Research Programmes supported under the Renewable Natural Resource Research Strategy from 1990 to 1994 and 1995 to 2005.

Research Programme		Allocation of RNR Research Strategy Budget (%)	
1990–94	1995–2005	1990–94	1995–2005
Integrated Pest Management	Crop Protection	33.0	26.4
Food Science and Crop Utilisation	Crop Post-Harvest	11.9	12.6
Forestry	Forestry	10.3	13.2
Livestock Production	Livestock Production	9.2	8.4
Animal Health	Animal Health	6.4	8.1
Resource Assessment and Farming Systems including	†Natural Resources Systems	6.0	14.2
Agricultural Engineering		1.5	
Plant Sciences	Plant Sciences	4.5	8.4
DFID Biotechnology	(*incorporated into Plant Sciences Programme*)	1.6	
Miscellaneous	Flexibility Fund	3.1	1.2
Fisheries	Fisheries‡	3.7	5.5
Socioeconomics – external		1.5	
Socio-economics – in-house		1.3	

† Initially managed by the DFID in-house and then contracted out.
‡ Included the programmes: Fisheries Management Sciences, Fish Genetics (later merged with Aquaculture), Aquaculture and Post-Harvest Fisheries.

on intended end users. In an attempt to redress the perceived lack of impact, the NRD introduced an initiative in 1993 designed to take existing research results to the field by requiring that a specified minimum proportion of each programme's budget was spent on location-specific adaptive research. This was based on the need to pay more attention to uptake pathways by linking strategic research by UK institutes with developing country organizations. However, it proved to be an ambitious assumption that there were many useful research outputs already 'on the shelf' that had not been adopted by the end user because of a lack of location-specific adaptive research. For many of the programmes much of the research agenda had been strategic and had not been designed to meet the demands of end users. This decreased the possibility of having outputs that could be easily applied.

Revised RNR Research Strategy (1995–2005)

A major review of the RNR Research Strategy took place in 1993, and in 1994 a revised RNR Research Strategy was published (widely known as the 'yellow brick' because of its weight and its yellow cover) (Research Task Group, 1994). It laid out in detail the RNR Research Strategy for the period 1995–2005 and much of the research management was again contracted out (Table 1).

The new strategy was a major innovation in both methods of research management and the commissioning of research. It was built on the requirement that all of the research had to be demand led. This was broadly defined as an identifiable constraint to development with quantified benefits that could be achieved and an identifiable community of beneficiaries (Research Task Group, 1994, p. 22). It also required that representatives of the beneficiaries had participated in defining their needs. Since the beneficiaries were very broadly defined, end-users were not always consulted. The PSP placed considerable emphasis on the potential impact of any proposed research and this was often quantified in an *ex ante* impact assessment. This could take into account whether the research outputs were a global public good, a factor not considered explicitly in the research strategy. Clearly identified uptake pathways were also required with target institutions that would take up the transfer of the products of the research to the end users. The uptake pathways were not defined at the end-user level, e.g. by gender or wealth class, but emphasized institutional arrangements for the packaging and promoting of research outputs.

DFID staff working in the field were asked to identify important researchable constraints in the natural resources according to the production system and the target country. This was a consultation within a small constituency of the possible stakeholders but helped DFID to link its centrally funded research with its field-based development activities, and thus made it more likely that, once relevant research outputs were produced, they would be promoted by DFID. The process of identifying demand was also narrow in that little attention was paid to the supply side of meeting the demand such as the likelihood that the identified constraint was solvable by research and whether the centrally funded programmes had research capacity within that area.

Introduction of logical frameworks

Another important innovation for research management was the introduction of logical framework (LF) methodology which gave a structured approach to research planning and management. The strategy as a whole had a set of nested logical frameworks. There was an overall strategy-level LF to which the individual research programme LFs, and the programmes' project LFs in turn, directly related. These programme LFs formed part of the competitive tenders and subsequent management contracts with universities and research institutions. The programme managers had DFID-specified goals and purposes (at the top of the hierarchy of the four levels, i.e. goal, purpose, outputs and activities) for their programme LF. The managers thus had to define outputs from commissioned activities that met the purposes and goals. In turn, individual projects had their own LFs that fed into the programme-level LF.

The introduction of the LF approach was a radical departure from previous research management and greatly helped to make the research more demand-led. If the research was curiosity driven it quickly became apparent that it could not contribute to the higher level objectives of the programme. However, the process of determining whether research was demand led or not could have been done without the LFs. In fact it might have been easier without, as both the managers of programmes and project scientists were unfamiliar with the methodology and so training was required. In addition, the nested design of the LFs meant that programme managers and project scientists could only write the activity and output levels of the LFs. Without the possibility of making simple changes in the higher levels of the LF, it made the construction of the LF more difficult. The programme level purposes were nested within the overall RNR Research Strategy LF such that the PSP purpose statements were equivalent to the RNR Research Strategy outputs and were worded in terms of *'production increased by 2005'*. This placed unrealistic demands on programme managers since the gap between the research outputs they were responsible for delivering and the purpose was too great and depended on other actors and policies. In view of this, the PSP management commissioned an independent consultant to examine the programme LFs and recommended to DFID a revised set. These were later approved by DFID and one outcome was that PSP purpose statements were revised to read *'productive potential increased'* rather than *'production increased'* (Jones, 1995).

The LF approach was originally designed for the management of projects where there was expected to be a good relationship between the delivery of inputs and the achievement of outputs. This relationship does not necessarily hold in basic or in highly innovative research where, at the project level, despite scientific excellence, outputs may not be achieved. At the longer-term programme level, the relationship between inputs and outputs is stronger because a proportion of the projects can fail without materially affecting the achievement of programme level outputs.

At the beginning of the new RNR Research Strategy 1995–2005, the stated goal in the strategy LF was *'the alleviation of poverty, the promotion of economic growth and of economic reform, and the mitigation of environmental problems'*. However, following the Millennium Development Goals agreed at the United Nations Millennium Summit in September 2000, the DFID changed the RNR Research Strategy goal to *'generate new knowledge and to promote its uptake and application such that the livelihoods of poor people are improved through better management of renewable natural resources'*. Unlike some other programmes the PSP's project portfolio remained largely unaffected by this change. This was because its research was already strongly focused on increasing productivity of crops such as pearl millet and upland rice for low-resource farmers in marginal agricultural environments, rather than focused on increasing economic growth by raising agricultural production in favourable areas. Of course, by doing so greater priority was paid to improving the livelihoods of poor producers rather than those of the urban poor who would benefit from the lower cost of food from increased production from more favourable areas. The arguments for doing so are complex, but the PSP held that agricultural research in favourable areas was already the highest priority of the National Agricultural Research Systems (NARS) and that production in favourable areas was affected more by economics (subsidies and international trade agreements) than by technical factors.

The introduction of LFs was a catalyst for change in both the management and the approach to specifying and procuring research within the DFID RNR Research Strategy. As the methodology has evolved it is clear that some elements of the LF approach are desirable such as the requirement for progress milestones, indicators of success and clear routes to uptake of the research. Some form of formal project management tool is needed and even if LFs themselves are not used, detailed descriptions of activities and expected outcomes are required and assumptions of risks are helpful. Research applications to, for example, UK Research Councils that do not use logical frameworks appear to lack structure for those familiarized with the RNR Research Strategy LF approach.

Refining demand-led research

Given the narrow basis for originally assessing demand described above, an initial management task was to refine the demand-led nature of commissioned research. In the case of the PSP, examples of some of the research that was re-assessed for demand included breeding for resistance to black Sigatoka disease in bananas, improvement of tolerance to high temperature in cotton, increased tolerance to drought stress in upland rice and increased resistance to disease and adaptation to marginal conditions in pearl millet. The programme managers were, with the agreement of DFID, able to revise these programme outputs in consultation with their Programme Advisory Committee (PAC). As part of this process, the PSP commissioned studies on demand assessment for research on cotton, banana, pearl millet, drought in rice and aluminium toxicity in wheat. These studies, by experts in the field, drew on a larger constituency than that originally used. They also considered the likelihood that research could solve the problem. For example, black Sigatoka disease in banana, although recognized as of great importance was not considered a researchable constraint with the technology available at that time (Johanson and Gowen, 1995). A review of the research on cotton (Tripp, 2000) identified a number of issues bearing on the effectiveness of support for cotton research in Africa and concluded that institutional deficiencies had to be addressed before considering further funding of research. On the basis of this, existing PSP funding for research on cotton was discontinued. The review of pearl millet highlighted the importance of increasing investment in research and development as very large gains could be made through the application of new technologies (Gill and Turton, 1997). Similarly, drought tolerance in rice was found to be an important researchable constraint (Craufurd, 1997).

The PSP also commissioned projects to assess demand for research. For example, the project *'Assessing the potential for short duration legumes in South Asian rice fallows'* used remote sensing to assess the extent of fallows following rainy season rice production in South Asia (Subbarao *et al*. 2001). It determined that there were about 15 million ha of fallows in India, Nepal and Bangladesh where PSP-funded technology, such as a seed-primed chickpea crop, could help farmers very profitably replace the fallow with a post-rainy season crop.

HISTORY OF THE PLANT SCIENCES RESEARCH PROGRAMME

In 1990, CAZS was awarded, following open competition, a contract to manage the PSP as one of the components of the RNR Research Strategy. The programme was to conduct research in two areas: crop physiology and plant breeding, each with a separate budget (which remained the case until 1996) and with targeted expenditure on different commodities. This complex matrix meant that balancing expenditure between plant breeding and crop physiology programmes and among commodities constrained selecting research that could best solve developing country agricultural problems. Even though a commodity basis for strategic research may be desirable, adaptive research requires an across-commodity approach. This weakness, of organizing research on a commodity-focused basis, was, and still is, common to most international and national agricultural research. The CGIAR has made progress on across-commodity research with initiatives such as the rice–wheat consortium in South Asia (Seth *et al.*, 2003), but most national programmes retain a rigid demarcation between the work of their commodity-based research institutes.

The new strategy shifted from a commodity focus to a system focus by having seven clearly defined RNR production systems (semi-arid, high potential, hillside, tropical moist forest, forest-agriculture interface, land-water interface and peri-urban interface). These classifications may have been useful for programmes such as the Natural Resources Systems Programme (NRSP) that concentrated on different farming systems. In the case of the PSP, most projects cut across these production systems and sometimes it was difficult to decide exactly which production system was targeted by a particular project. For these reasons, PSP management did not find the production system classification a particularly valuable tool in managing the research and completely removing category-based management tools may have been preferable. Over time, the PSP management found that research themes (see below) were the natural way of managing the programme even though, earlier in the research strategy, this approach would have been considered to be too 'technology-driven'. Basic research on, for example, genetically modified crops, which offered research solutions to problems that were intractable by other means, was an obvious technology-based division within the programme but was still demand led as it was applied to problems where evidence for demand was high. Another research theme, participatory technology development (PTD), was also defined by a particular approach to research. However, compared to the transgenic research, it was more diverse and comprised both agronomy and breeding, the latter supported by basic molecular marker research. Participatory technology development was also designed to produce outputs where important constraints had been identified. Hence, if firmly rooted in demand, research programmes can be analysed in many ways (production system, geographical, commodity, technology, or on how basic or adaptive it is). What is most effective will depend on circumstances and in the case of the PSP it resulted in a theme-based approach where the themes were defined by the technical approach, i.e. molecular marker technology, genetic transformation or participatory approaches. In 1990, the PSP inherited three major research areas, all based on the discipline of crop physiology and which had enjoyed long-term funding from the DFID, most since the early 1980s. These were:

- photothermal responses in crop species (e.g. Roberts *et al.*, 1995)
- salinity tolerance in cereals (e.g. McDonnell *et al.*, 1983)
- thermotolerance in pearl millet (e.g. Howarth, 1991).

These continued to be funded during the pre-1995 RNR Research Strategy and were included in the logical framework for the PSP in the 1995–2005 strategy,

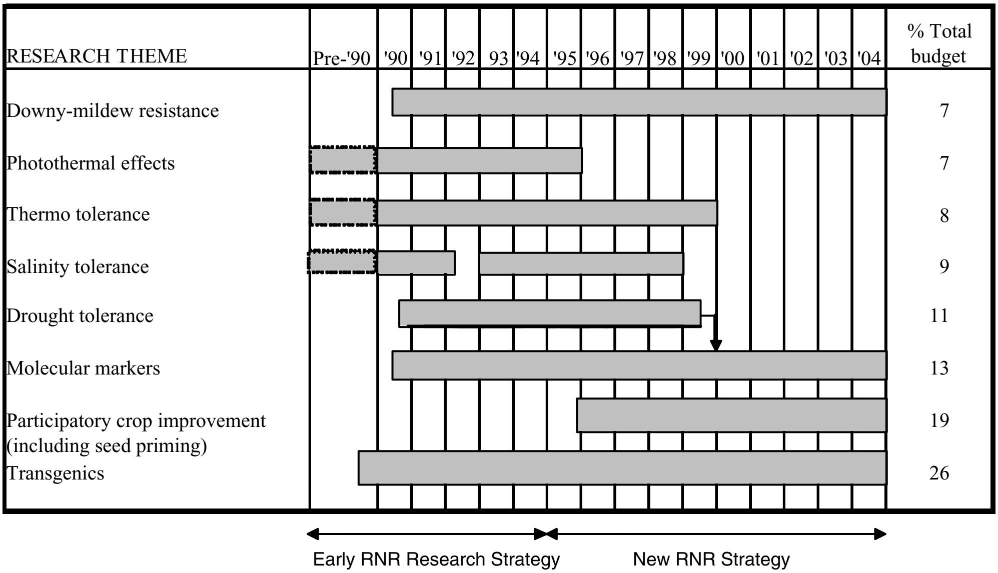

Figure 1. Major research themes funded by the Plant Sciences Programme before (pre-1995) and after the start of the new Renewable Natural Resource (RNR) Research Strategy in 1995. Bars show the period over which projects were funded and the approximate percentage expenditure during the period 1990–2004.

revealing a possible weakness in how demand had been established. The managers commissioned a review of research on photothermal effects and, since this concluded that it could not lead to impacts on livelihoods within a reasonable time frame, funding was discontinued in 1996 (Figure 1). Research on salinity tolerance in cereals was refocused towards uptake by farmers and moved from controlled-environment experimentation in the UK to field screening and testing in Pakistan and India. However, this was only partially successful, because the research on salinity tolerance produced new wheat varieties that were not sufficiently outstanding for them to be widely and rapidly adopted. As a result, the work was discontinued in 1999 (Figure 1).

The thermotolerance research underwent a major review (Moorby *et al*. 1993) when it was realized that the physiological approaches used, with their emphasis on heat shock proteins (Cavan *et al*. 1996a; 1996b; 1996c), were unlikely to produce outputs that would have any impact within the lifetime of the RNR Research Strategy. As a result, the lead institute, Institute of Grassland and Environmental Research (IGER), shifted its focus away from thermotolerance and heat shock proteins towards drought-tolerance research (Yadav *et al*. 2002; 2003). This change took place prior to 1995 but anticipated the need for demand-led research as drought was the most important abiotic constraint to pearl millet production. The PSP management encouraged IGER to integrate their drought tolerance work with the ongoing research on molecular marker mapping in pearl millet for resistance to downy mildew disease (Jones *et al*. 1995) that had been funded by the PSP since 1990. After 1995, molecular marker trait

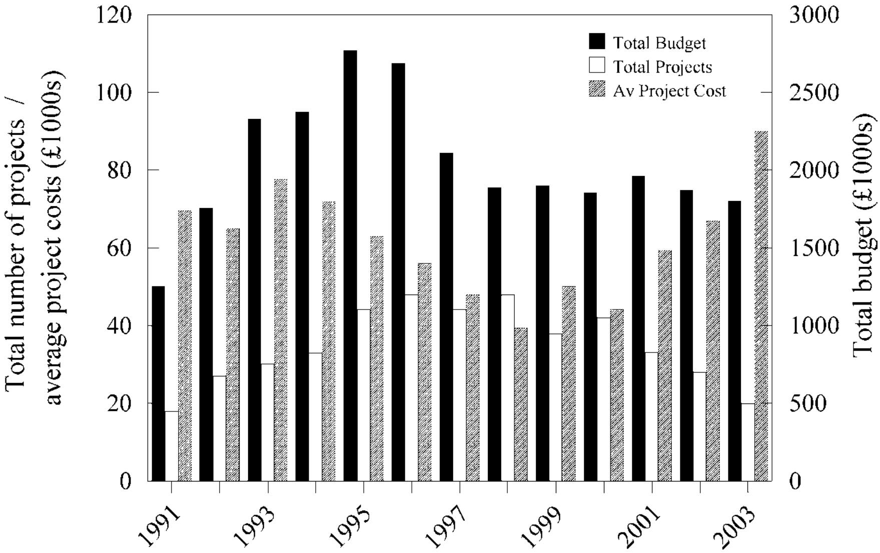

Figure 2. Annual budget, total number of projects and average project costs for the Plant Sciences Research Programme, 1991–2003. For this across-year comparison the value of the £ sterling has been deflated relative to its value in 2002/2003.

mapping became a dominant feature of the drought-tolerance research and these two research topics became increasingly more integrated (Figure 1).

Changes in the PSP research budget

Along with changes in approach, there were also changes in the amount of funding available, although there was always a substantial 'core' budget that allowed for the long-term funding of important research themes. Allowing for inflation, the annual budget fluctuated between a minimum of £1.25 million in 1990/1 and a maximum of £2.8 million in 1995 (Figure 2). The number of projects funded in 2003 (20) was similar to that at the start of the RNR Research Strategy in 1990, but their average cost (allowing for inflation) had increased by almost 30 % (Figure 2). The higher project costs reflected the increased cost of science in relation to inflation, particularly in biotechnology, and because UK universities and research institutions moved towards charging full costs. In addition, a number of PSP research projects were amalgamated (see below).

Research topics

Over the period of the strategy fewer crops have been studied (Figure 3) and the range of research topics reduced. In 1994, PSP research encompassed 16 different crops compared with only 10 in 2003. The decline in crops studied and number of research topics was because of the decline in real terms in funding and because of a concentration on research considered the most likely to have a major impact on providing benefits to poor farmers within the fixed time frame of the RNR

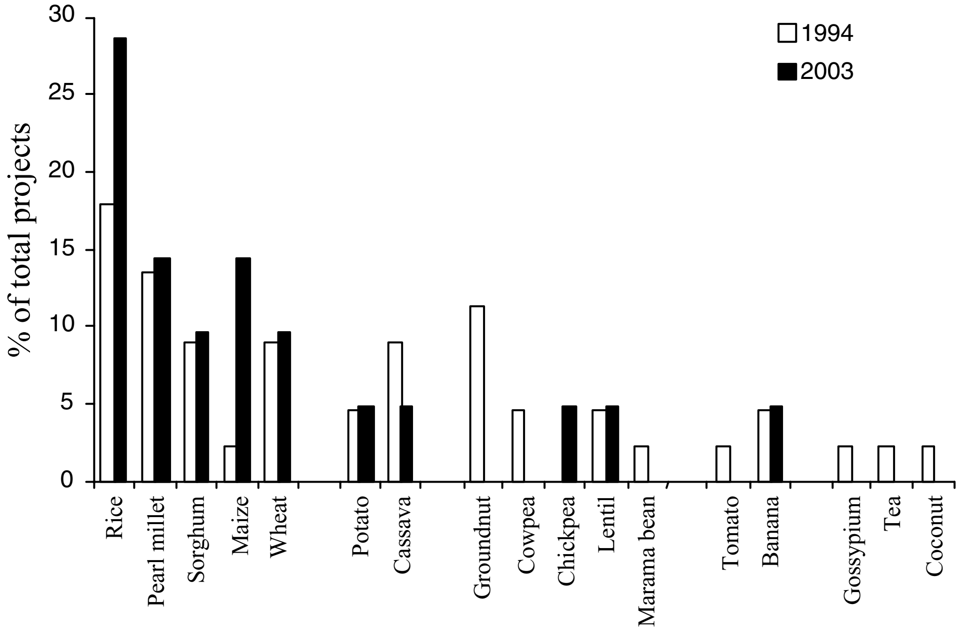

Figure 3. Comparison of the percentage of projects per crop funded by the Plant Sciences Programme near the beginning (1994) and towards the end (2003) of the RNR Research Strategy. The total number of projects was 45 (1994) and 21 (2003).

Research Strategy. Over the period of the strategy, the research became more farmer participatory. This clearly made the research more demand led, i.e. more sensitive to client needs, and the participation of farmers also helped to promote the uptake of research results.

CURRENT PSP RESEARCH THEMES

As the end of the strategy approaches (March 2006), the programme has only three research themes, where the themes are defined not by developmental constraint but by technical approach: molecular marker technology to assist plant breeding, transgenic crops and participatory technology development. Each theme targets more than one constraint. The molecular marker research is concentrated on breeding for resistance to downy mildew (pearl millet) and drought-tolerance (pearl millet and upland rice); transgenic work is targeted mainly at nematode resistance in three crops (rice, cooking banana and potato) and also at resistance to rice yellow mottle virus; PTD in cereals and legumes is targeted at improving crop productivity under conditions where good crop establishment is difficult in drought-prone areas with low soil fertility. All dated from 1990, except for PTD that only started under the new strategy plan of 1995–2005, although components of PTD were developed by the managers outside of the PSP pre-1995 (Harris, 1996; Witcombe *et al.*, 1996).

Drought tolerance has been a major component of PSP research in both phases of the RNR Research Strategy, with an expenditure of almost £2 million between 1990 and 1999, amounting to just over 10 % of the total PSP budget (Figure 1). Initially the research adopted a predominantly physiological approach (Clark *et al.* 1996; Tomos and Pritchard, 1994), but as it matured and as the RNR Research Strategy became more concerned with uptake, the emphasis switched to molecular marker techniques (mapping quantitative trait loci [QTL]) and the development of closer links with applied plant breeding programmes (e.g. Price and Courtois, 1999). Hence, by the late 1990s most of the drought-tolerance research employed the highly cost-effective QTL approach.

Over time, the outputs from the programme's strategic research have been applied in practical plant breeding programmes in participatory crop research. For example, the participatory plant breeding project, *'Marker Assisted Selection for Participatory Plant Breeding in Rice'* has integrated molecular marker techniques with PTD to improve uptake and response to demand.

In the following, we discuss the essential ingredients that have contributed to the success of the PSP, using the present three research themes as case studies. A key, in the light of the time needed for plant science research, was the provision of continuous, long-term funding to allow projects sufficient time to develop and produce outputs of real value to end users. In addition, the PSP only commissioned research that:

- was demand led
- was well-designed and managed with in-built flexibility to allow for changes in circumstances
- involved a network of partners with appropriate and complementary skills
- had clearly identified uptake pathways.

We first review two strategic research themes, transgenic crops and molecular markers, to illustrate the benefits of the above approach. We then give the example of PTD research in south Asia to illustrate how, over time, funding has shifted from projects in UK research establishments to a network of overseas partners that benefit from interactions with UK scientists.

Transgenic crop research

Amongst the PSP research themes, transgenic crops have received the most funding, 26 % of the total PSP budget from 1990 to 2003 (Figure 1). Over the past ten years the transgenic research has:

- developed more reliable and efficient transformation systems for rice and banana (James *et al.*, 2002)
- developed a 'clean gene' transformation system for rice that does not transfer unwanted genetic sequences along with the target transgene (Afolabi, 2003; Vain *et al.*, 2003)
- analysed transgenic loci and aspects of gene silencing in rice (Kholi *et al.*, 1999)

- produced transgenic material resistant to Rice Yellow Mottle Virus (RYMV) (Pinto *et al.*, 1999)
- produced transgenic rice and potato that are resistant to nematodes (Atkinson *et al.*, 2003; Urwin *et al.* 2001; 2003).

During the early RNR Research Strategy, the PSP funded 15 transgenic crop projects on six different crops (cassava, groundnut, potato, sorghum, sweet potato and rice). In 1995, the number and range of projects was reduced to give a better balance between strategic research and research with shorter-term objectives. As a result, the PSP focussed its research on two main areas, RYMV-resistance in rice in response to demand from the Africa Rice Centre (WARDA) and nematode resistance in three crops – rice, banana and potato.

Resistance to nematodes had a clearly identified demand. Potato nematodes alone account for a 13 million t loss of yield in the developing world and, globally, banana and rice suffer estimated annual yield losses of 20 % and 10 % respectively, due to nematodes. Nematode resistance was considered to be a good target for transgenic research. First, there was limited resistance in the conventional gene pool. Second, transgenic approaches are also potentially much faster because breeding is a very long-term process in potato, and breeding banana, a clonal crop, is extremely difficult and third, there were no effective, environmentally friendly methods of nematode control. In all banana-growing countries, nematodes are controlled, with limited success, by the application of environmentally harmful and expensive nematicides. The genetic modification was highly biosafe as it involved transferring genes from maize and rice that expressed a protein (cystatin) which is found in the grain and so was already consumed by billions of humans as part of their diet. The cystatin prevents the nematodes from digesting proteins so they are malnourished, develop slowly and reproduce much less.

When the PSP started funding transgenic work in 1994, the UK had no established ability to produce transgenic plants in rice. By the end of the first two projects, transgenic rice plants resistant to RYMV had been produced (Pinto *et al.*, 1999). Regulatory approval was then required to test the products in the field but none of the developing countries in Africa, in which RYMV was a problem, had a biosafety regulatory structure in place. This constraint had been recognized in the project LF but, at the time the project was written, strong European opposition had not emerged to what has proven to be, over a substantial period, as safe a technology as any used in agriculture.

The absence of an appropriate regulatory framework also limited the impact of PSP's research on nematode resistance which, as with RYMV, was very successful. As a model, high levels of nematode resistance in potatoes were demonstrated under field conditions in the UK using plants expressing the chicken egg-white cystatin (CEWc) (Urwin *et al.*, 2001). This work was then repeated in 1999 with the target transgene, rice cystatin. A high level of resistance was found and when combined with natural resistance, or another transgene, it should provide a more robust field resistance (Atkinson *et al.*, 2003).

Overall, the PSP has produced a considerable amount of new knowledge that will almost certainly be used to produce widely cultivated, RYMV- and nematode-resistant transgenic crops in the years to come. The lack of impact of this research with farmers over the period of the research strategy was because governments in the target countries had not put in place appropriate legislation. Nevertheless, it seems likely that as more developing countries cultivate transgenic crops and as more data emerge on their environmental and financial benefits (James, 2004), transgenic technology will be widely adopted by developing countries.

Molecular marker research

Pearl millet molecular marker research illustrates the success of long-term (15 years) plant science research. The PSP spent over £2 million in this period to support research in the UK and India and to facilitate linkages among partners. This has required long-term collaboration among research groups with complementary interests and expertise. Linkages were maintained by international and national annual meetings organized by the programme managers (ODA, 1993; 1996).

The molecular marker research was demand led; to ensure that it had potential for substantial impact, the first practical attempt at marker-assisted maintenance breeding for downy mildew resistance in pearl millet was in the genetic background of a single-cross hybrid, HHB 67 that was becoming very popular with Indian farmers. This hybrid, released for cultivation in 1989, became the most popular public-sector-bred pearl millet hybrid in India, occupying >70 % of the pearl millet area in the state of Haryana in 2001. Genetically uniform single-cross hybrids are much more vulnerable than traditional open-pollinated varieties to downy mildew disease and a popular hybrid such as HHB 67 represented a downy mildew epidemic waiting to happen. Such an epidemic would result in an estimated loss of at least £7.8 million worth of grain yield in the first year.

The research was long-term and designed to solve not only this particular problem but create new tools for breeding pearl millet. It involved the following steps:

- marker development
- linkage map construction and extension
- use of maps for QTL analysis
- marker-assisted backcrossing programmes
- testing of new breeding products, ultimately leading to
- official release and the adoption of the best improved cultivars by farmers.

Trait mapping was conducted simultaneously with map development so that by the time the initial marker-based genetic linkage map of pearl millet was published (Liu *et al*., 1994), QTLs for downy-mildew resistance had been identified by CAZS and the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) (Jones *et al*., 1995, 2002; Breese *et al*., 2002). A short-time later, QTL mapping for drought tolerance was initiated by IGER and ICRISAT (Yadav *et al*., 2002) and the pearl millet genetic linkage map was recently updated (Qi *et al*., 2004).

'HHB 67 Improved', a downy mildew resistant version of the popular pearl millet hybrid HHB 67 produced by this research, was officially released by the Haryana State Varietal Release Committee in 2005. Marker-assisted backcrossing for target QTLs has produced unexpected benefits. Yield advantages, first identified in multilocational trials in 2001, were confirmed in 2002 and 2003. These gains in grain and stover yield, under conditions where disease pressure was not a factor, were as good as, or better than, conventional breeding for yield even though, in this case, the marker-assisted backcrossing programme had not consciously sought to improve yield itself. The yield gains came from a genetic contribution for yield from the downy mildew resistant donor parent and from selection of the best hybrids in trials of hybrids that were an integral part of the marker-assisted breeding methodology.

Participatory technology development in south Asia.

The PTD work of PSP has produced, so far, the greatest benefits to farmers (see below). The research was demand led by using participatory techniques to elicit from the clients or beneficiaries of the research the most important production constraints. Those that were researchable were then prioritized. It also led to a much better understanding of all the mechanisms involved in delivery of outputs. In Asia, improved rice varieties have been produced using client-oriented approaches (Virk *et al.*, 2003; Witcombe *et al.*, 2005) and then disseminated to the wider farming community using local seed supply systems. For maize in Asia, farmer-participatory selection and breeding has generated improved open-pollinated varieties that give 20–30 % increases in grain yield (Tiwari *et al.*, 2004). By using highly client-oriented approaches to plant breeding, rates of adoption have been high amongst farmers, mainly on marginal lands, who had not previously adopted the products of conventional plant breeding programmes.

The PTD in south Asia focussed on two main themes:

- the production of high-quality, stress-tolerant rice varieties for Nepal, Bangladesh and India using highly client-oriented plant breeding and participatory varietal selection
- the reduction of fallows following rice in Nepal, Bangladesh and India using low-cost, low-risk technologies (e.g. seed priming, micronutrient stress alleviation, and appropriate new crops and crop varieties).

Much of this work built on the successes of previous projects, including some of the earlier strategic research on drought tolerance and molecular marker technologies. This includes seed priming, the benefits of which were first established by a project funded in 1996 (Harris *et al.*, 1999; 2001b) and which is now used effectively in a farming systems context in projects in Bangladesh, India, Nepal, Pakistan and elsewhere (Harris *et al.*, 2001a; Musa *et al.*, 2001; Rashid *et al.*, 2004b). Further work has shown seed priming to be an effective vehicle for cost-effective delivery of micronutrients, e.g. molybdenum (Johansen *et al.* 2005) and zinc (Harris *et al.*, 2005) as well as a low-cost component of integrated pest management approaches (e.g. Musa *et al*., 2001; Rashid *et al*., 2004a).

The highly client-oriented plant breeding programmes (traditionally, but less precisely, also called participatory plant breeding, see Witcombe *et al*., 2005) have proven to be outstandingly successful. Two maize varieties and two rice varieties (reviewed by Stirling and Witcombe, 2004) from PSP-supported client-oriented breeding programmes have been released in India. Other rice varieties are in the pre-release stage in Nepal and are already being disseminated by government agencies (Joshi *et al*., 2002). The same varieties have proven to be extremely acceptable by farmers in Bangladesh as they offer not only substantially improved yield and quality but also mature earlier than varieties from the NARS. A major reason for the success is that all of the varieties from these client-oriented programmes have been bred to meet the particular needs of resource-poor farmers. Moreover, this has been done much more quickly than is usual in conventional, research-station-centred approaches because the delay between on-station testing and testing with farmers was eliminated. The increase in yields of grain and stover and the superior grain qualities of both the rice and maize varieties are having a considerable impact on the livelihoods of poor farmers. The PSP has commissioned outcome assessment studies that have quantified the adoption of varieties and their improved utility for farmers. This has allowed financial analyses to be made and, for one case, the total anticipated benefits to upland rice farmers from adopting new upland rice varieties in eastern India are far greater than the total expenditure of the PSP during the current strategy and equal the overall total expenditure of the RNR research strategy (Virk *et al*., 2003).

Instrumental to the success of the PTD work has been the development of a strong international network which has greatly contributed to capacity building and facilitated the exchange of germplasm and ideas between partners. For example, the rice breeding programme in Nepal carried out by LI-BIRD and CAZS Natural Resources with the collaboration of NARC has established linkages with non-governmental organizations (NGOs) and GOs in Nepal, Bangladesh, India and, for maize, Pakistan. A PSP-funded, in-country coordinator based in Kathmandu, Nepal has been a vital catalyst in promoting institutional acceptance of client-oriented approaches to plant breeding and varietal selection. The research co-ordinator has played a major role in the establishment and encouragement of international partnerships in the region. This now involves four countries (Nepal, Bangladesh, India and Pakistan) and many partners (Table 2).

These international networks have increased in importance as the strategy has progressed. As the research has increasingly concentrated on 'packaging and promoting' the research outputs so more money has been spent in developing countries; increasing from 5 % of the PSP budget in 1990 to 40 % in 2003. Indeed, to promote research outputs some of the research money has been spent in non-traditional ways that would not normally be considered strictly as research. For example, the PSP has funded the production and distribution of seeds of new varieties and new crops. This type of scaling up is action research (McTaggart, 1997) where the value of research outputs can be validated on a wide scale whilst increasing impact.

Table 2. Partners formally and informally involved in the PSP-funded participatory crop improvement research in south Asia. The network is extensive so the list is not exhaustive.

Acronym	Organization
ASA	Association for Social Advancement, Dahod, Gujarat, India
AKRSP	Agha Khan Rural Support Programme, Pakistan
AVRDC	Asian Vegetable Research and Development Center, Taiwan
BARI	Bangladesh Agricultural Research Institute
BAU	Birsa Agricultural University, Ranchi, Jharkhand, India
BHU	Banaras Hindu University, Varanasi, Uttar Pradesh, India
BRRI	Bangladesh Rice Research Institute
CARE	CARE, Nepal
CRS	Catholic Relief Services, India
CIMMYT	International Center for Maize and Wheat Improvement, Mexico
CIRAD	Centre de Coopération Internationale en Recherche Agronomique pour le Développement, France
DAE	Department of Agricultural Extension, Bangladesh
DADOs	District Agricultural Development Offices (of the Department of Agriculture), Nepal
FORWARD	Forum for Rural Welfare and Agricultural Reform for Development, Nepal
GAU	Gujarat Agricultural University, Ahmedabad, India
GVT	Gramin Vikas Trust, New Delhi, India
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics, India
IRRI	International Rice Research Institute, Philippines
JNKVV	Jawaharlal Nehru Krishi Vigyan Vidhyalaya, Madhya Pradesh, India
LI-BIRD	Local Initiatives for Biodiversity, Research and Development, Nepal
MPUAT	Maharana Pratap University of Agriculture and Technology, Udaipur, India
NARC	Nepal Agricultural Research Council
NSB	National Seed Board, Nepal
NWFPAU	North West Frontier Province Agricultural University, Peshawar, Pakistan
IRD	Institut de Recherche pour le Développement
PARC	Pakistan Agriculture Research Council, Islamabad
PETRRA	Poverty Elimination Through Rice Research in Asia, Dhaka, Bangladesh
PLAN	PLAN, Kathmandu, Nepal
PROVA	Peoples' Resource Oriented Voluntary Association, Bangladesh

Action research on seed systems and seed supply has allowed the programme's research outputs to be more efficiently disseminated. In a similar way, impact assessment has contributed to the research programme by providing valuable information on uptake pathways and feedback into project design.

CONCLUSIONS

The research model of an 'institute without walls' that commissions research that is demand led and accounts for uptake pathways has been successful. Similar expenditure, using the same model but without the demand-led focus had been far less effective in delivering benefits to poor farmers. The model can be compared to others.

Compared to the Consultative Group for International Agricultural Research (CGIAR), the PSP has not been constrained by having traditional partners in the NARS, the formal government-funded research institutes, and has been able to build partnerships based on NGOs who in turn have brought in the collaboration of government agencies.

An alternative model to the 'institute without walls' is to fund research in the National Agricultural Research and Extension Systems (NARES), an approach that is being tried by DFID in their bilateral programmes. We would be wary about any bilateral approach that did not specifically provide funds for international collaboration in science. All science is now international and no country can make significant progress in isolation. Given the relatively much higher cost of Organization for Economic Co-operation and Development scientific input, it is unlikely that NARES will use funds given to their local institutes to purchase such expensive, external inputs. When bilaterally funded projects do bring foreign and local expertise together in research programmes, such as the DFID-funded Poverty Elimination Through Rice Research in Asia (PETRRA) in Bangladesh, they may not last for sufficient time to have great impact. Such projects are vulnerable to being stopped because they may be seen to have too many overheads for relatively small expenditures or new in-country staff may not appreciate the value of research.

In France, the model of CIRAD (Centre de Coopération Internationale en Recherche Agronomique pour le Développement) and IRD (Institut de Recherche pour le Développement), formerly ORSTOM, has the disadvantage that most of the expenditure tends to be in the host country. Generating demand-led research agendas within such institutes is difficult unless there is a mechanism that requires a high proportion of the budget to be spent outside of the institute itself.

Other research models share features of the management model of the PSP. The Collaborative Research Support Programmes (CRSP) in the US contracts out research. The manager of the Peanut CRSP (T. Williams, personal communication) stresses that outsourcing research has the advantages of flexibility and the ability to choose the highest quality science among competing bids. We concur with this and conclude that one of the most effective models is a centrally funded, demand-led research programme with the flexibility to contract research out to those that can most efficiently conduct it. One constraint to the model, however, is the potential discontinuity created by the need for DFID to tender management contracts competitively, and to untie its aid. In research, long-term funding is a prerequisite for success. There is also a need for at least some institutional continuity. Functioning networks of institutions take a long time to establish and require a continuing effort to maintain. Big changes in institutional arrangements can disrupt the functioning of these partnerships to the detriment of impact. The best model will combine the advantages of long-term institutional continuity with the flexibility of the 'institute without walls' model.

The current RNR Research Strategy (the 'yellow brick') has greatly increased the relevance and effectiveness of DFID's natural resources research. The revision and implementation of the revised RNR Research Strategy in 1995 represented a major innovative step in relating research to demand and changed researchers' perspective from one that was activity-based to one that was output-based. A comparison between the PSP in 2004 and 1991 inevitably concludes that the programme has been transformed: unlike in 1991, research is now firmly demand driven, much more of it is based in developing countries, both horizontal and institutional impact are integral parts of project design, and many farmers are benefiting from the outputs of the research. Major contributions to success were: the demand-led focus of the research; the development of effective overseas networks involving not only scientists but those with the most appropriate expertise for uptake; and long-term funding despite short-term project horizons. In any future research strategy long-term (10 year) projects with sufficient funding to build the capacity of in-country partnerships to ensure the adoption of research outputs would build on this success.

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