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WHAT ENABLES INNOVATION IN THE PRIVATE SECTOR? LESSONS FROM THE DEVELOPMENT OF SALT-TOLERANT HYBRID RICE

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Abstract: Under what circumstances can a private company succeed in developing new crops? This paper examines the experience of an Indian seed company that sought to use an advanced new technology (molecular breeding) to develop a salt-tolerant form of hybrid rice. It demonstrates that the company's success was made possible by its effective linkages with national and international institutions, which mean that the company received indispensable inputs to its work; namely DNA sequence data from the global public domain and germplasm from the Indian public sector. Provision of these inputs was *not* mediated by a market system: indeed, recent changes that tend to make such interactions subject to market forces, notably the commodification of germplasm, have increased transaction costs and been a source of inefficiency. At the same time, the internal characteristics of different parts of the firm meant that (i) a number of technically demanding tasks were successfully completed; but (ii) progress was slower than could reasonably have been expected and (iii) at one point the project suffered a severe setback. These experiences confirm the innovation systems framework and also highlight the critical importance of the internal culture of a firm in determining success or failure in innovation. Interestingly, they also demonstrate that key aspects of organisational culture may vary between different parts of the same company. Copyright © 2007 John Wiley & Sons, Ltd.

Keywords: marker-assisted selection; biotechnology; India; intellectual property; germplasm

1 INTRODUCTION

Under what circumstances can a private company succeed in developing new crops? To answer this question, two distinct approaches will be used to analyse the experiences of an Indian seed company as it sought to use an advanced new technology (molecular breeding)

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to develop a salt-tolerant form of hybrid rice. These two approaches are: the 'Innovation Systems' framework (Hall and Rasheed Sulaiman, 2002), which represents innovation as a process that requires complementary contributions from a range of diverse actors and institutions; and the 'Fifth Generation' model (Rothwell, 1992), which concentrates on firm-level factors. The first approach emphasises the importance of relationships linking different and complementary actors, and the ways in which public policy may modify these relationships. In part, then, this paper examines the institutional landscape within which the company studied is situated, enquiring whether this landscape is structured in a way that enables the company to obtain the inputs that it needs and whether recent policy changes will help or hinder the provision of such inputs to innovation.

Such an examination of the *context* of a company can, however, only provide a partial explanation of its success or otherwise in developing new crops. It may explain why a company can or cannot obtain inputs for its innovative activities, but reveals little about how effectively or otherwise the company makes use of such inputs. These issues were explored by Rothwell (1992), who observed that effective innovation involves co-ordinating a range of distinct activities that take place in different departments, sometimes separated by organisational boundaries. His work thus highlights the importance of developing organisational forms that facilitate trans-functional communication: indeed, he describes the overall pattern of the innovation process in terms of 'a complex net of communication paths... linking together the various in-house functions'. While his focus was on activities within the firm, he stressed that these communication paths transcended its boundaries and thus served to link it 'to the broader scientific and technological community and to the marketplace' (*Ibid* p. 222). He noted that in all reported cases of successful innovation 'the emphasis is on interdisciplinary teams with the maximum sharing of information across functions' (*Ibid* p. 225).

The effectiveness of such teams may, however, depend on wider organisational considerations, such as encouragement to shift effort away from work within a single function in order to contribute to joint projects, the rules for evaluating the contributions of each individual and for distributing the rewards for collective achievements (Quinn *et al.*, 1996). This paper therefore seeks to identify those aspects of the company's culture that helped or hindered cross-functional working in general, and collaboration between plant breeders and biotechnologists in particular. The nature of molecular breeding is such that contributions from both of these disciplines are indispensable for any project employing this technology, and so this is the relationship that receives most attention.

These themes are explored in the remainder of this paper. The data on which it is based were obtained by means of a series of semi-structured interviews with those company employees most closely involved in the events reported. Thematic analysis was employed to interpret the findings from these interviews, with data analysis beginning well before data collection finished. This procedure meant that emergent themes could be explored in later interviews, with most informants being interviewed at least twice. The paper begins by introducing the company and its products and describes the creative way in which the company responded to the needs of its key market by obtaining, selecting and using specific inputs from the public sector. The following section discusses the company's work to develop a form of hybrid rice that could be planted in saline soil. It notes that the company received indispensable inputs from external organisations, namely DNA sequence data from the global public domain and germplasm from the Indian public sector. Provision of these inputs was *not* mediated by a market system: indeed, recent changes that tend to make such interactions subject to market forces, notably the commodification of germplasm, have increased transaction costs and been a source of inefficiency. The task of obtaining and selecting these inputs was shared by staff of the plant-breeding and biotechnology function, who displayed an impressive degree of mutual understanding and respect for each other's particular expertise. However, the manner in which the role of plant breeder was defined by the company, together with the management priorities applied to the breeding function, was less helpful to the project.

2 THE COMPANY AND ITS PRODUCTS

ACME Agri-Tech (pseudonym used to maintain company confidentiality) was founded in the early 1990s, at a time when only 12 private companies were active in India's newly liberalised seed market (Newell, 2003). A decade later, ACME made a small investment in biotechnology: a rented house was turned into a new laboratory, while two greenhouses were constructed. At this stage the main activity of this laboratory was to provide quality control. ACME developed methods to ensure that a batch of seeds met defined purity standards by screening DNA derived from a sample of the seeds in each batch. These methods were initially applied to sunflower, cotton and tomatoes, since uniformity is particularly important to farmers producing these commodities, and enabled ACME to provide highly pure seeds and so increase its share of the market.

As a private company, ACME relies on the income from seed sales for its very existence. This income is threatened by the absence in India of an effective system of intellectual property protection, so that farmers cannot be prevented from sowing seed saved from the previous season's harvest, rather than buying fresh seed each season. Hybrids offer a solution to this problem: plants that have been fertilised by pollen from another variety produce seed (F1) that grows vigorously (hybrid vigour) and produces a high yield, but seed saved from such hybrid plants (F2) does not 'grow true' and in turn produces unsatisfactory harvests. ACME therefore markets only F1 hybrid seeds, not open-pollinated varieties (OPVs). (At one time it developed and marketed seed of open-pollinated varieties, but lost money as a result of farmer seed-saving.)

Until recently, this commercial imperative to produce only hybrid seed severely constrained the capacity of the private sector to service India's major markets for rice seed. This was because all the materials available for producing hybrid rice had quality characteristics that were not acceptable to consumers in South India and therefore to the bulk of India's rice farmers. The problem arose from a particular technology used in hybrid rice production: hybrid seed is produced when a female parent is fertilised by pollen from a plant of another line/variety, and so it is vital that the female parent does not produce viable pollen (otherwise it will simply fertilise itself). Such male-sterile lines are rare, and were originally discovered in the temperate climate of China. The International Rice Research Institute (IRRI) succeeded in producing a limited number of cytoplasmic male-sterile (CMS) lines that were adapted to tropical climates,[1] and most of the hybrids commercialised in the tropics were based on the line IR58025. While these hybrids out-yielded comparable high-yielding varieties by 15–20 per cent, their grain quality meant that they were not accepted in parts of India and Bangladesh (Zaman *et al.*, 2002).

Interviews with ACME staff explained why the grain produced by these rice hybrids was not suitable for markets in much of South Asia. According to Watson (identity changed to

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[1] The DNA responsible for such male sterility is found in the cytoplasm of each cell (outside the cell's nucleus), while most other DNA is contained within the nucleus.

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ensure anonymity), ACME's Director of Biotechnology, hybrid rice was more sticky than its varietal equivalent, and produced a basmati-like aroma. As a result, when it was introduced to south India 'hybrid rice failed, because of the stickiness, because they eat, you know, friable kind of, you know, rice which is not sticky at all'. The stickiness and aroma of hybrid rice meant that farmers who grew it had to sell their harvests at a discount and so were unwilling to buy more seed. ACME therefore investigated why these undesirable traits were present in hybrid rice in India and established that virtually all of it was produced using just two CMS lines from IRRI: IR 58025 and IR 62829. Both of these lines have a background with high amylose content, while one of their parents was a basmati line, and so 'almost all the hybrid rice will carry this stickiness and aroma'. This problem partly explains why, as recently as 2004, hybrids occupied only a little more than one per cent of the area of India planted to rice.[2]

In response, scientists at IRRI worked to develop parental lines that would make possible the production of hybrids meeting regional quality requirements (Zaman *et al.*, 2002). IRRI's *Highlight of Achievements in 2002* thus reported the identification of CMS lines 'possessing mild to no aroma and intermediate to high amylose', noting that they could be used 'to develop hybrids possessing no aroma and non-sticky cooked rice grains' (IRRI, 2003, p. 7). Further collaborative work between IRRI and the Indian Council of Agricultural Research (ICAR) led to the release in India of non-basmati male-sterile material, and in 2003 ACME began working with one such line, known as RV-2A (and its maintainer line RV-2B).[3] ACME used this material in a number of projects, including the development of its hybrid Lucky 7 (name changed to maintain company confidentiality), which was released in 2004 and was an immediate commercial success, as well as longer-term work to develop rice hybrids that could tolerate insect attacks and saline soil.

3 THE SALINITY-TOLERANCE PROJECT

This project began with a proposal written by scientists in ACME's biotechnology laboratory and submitted to its Board. Sulston (identity changed to ensure anonymity), who at that time had recently joined ACME, explained that the problem of salinity was well known and so it was clear that there would be considerable market demand for a salinity-tolerant hybrid that satisfied farmers' other requirements. Such a hybrid was to be developed using molecular breeding: a rice-line (as yet unidentified) that grew well under saline conditions would be crossbred with a parent of the company's hybrid. However, this breeding work would be guided by analysing DNA extracted from the seedlings involved and testing for the presence (or absence) of molecular markers—specific DNA sequences known to be statistically associated with the presence of genes involved in the trait in question, in this case salinity tolerance.[4] The project, then, could only be implemented by a cross-functional team drawn from the company's breeding facility and biotechnology

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[2] This figure was given in interview by the head of ACME's Marketing department. It is consistent with official figures: in India, in 2004, rice was grown on nearly 45 million hectares, of which 560 thousand hectares were planted to hybrid rice (ICAR, 2005).

[3] The maintainer line is very similar to the male-sterile line, but does produce viable pollen. Male-sterile plants (in this case RV-2A) can thus be fertilised with pollen from RV-2B plants in order to produce a new supply of male-sterile seeds, and hence plants.

[4] For a review of this technology and its implications for development, see Reece and Haribabu (2007). For a more technical account, see Collard *et al.* (2005).

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laboratory. Accordingly, it was jointly planned by the biotechnologist Sulston and the rice breeder Borlaug (identity changed to ensure anonymity), who later met the company's vice-president to plan the project in detail. Resources were allocated: the project was expected to require additional laboratory facilities and the equivalent of a full-time scientist throughout its 6-year duration.

3.1 Obtaining and Selecting Germplasm and Markers

Work on the project began with efforts to obtain the breeding materials to be used for the initial cross. At that time ACME possessed two main CMS lines and five hybrids, either already on the market or in development. Sulston needed to choose which of these would benefit most (in commercial terms) from the addition of salinity tolerance. He therefore had to identify a hybrid parent that had strong market potential but was susceptible to salinity, since little or no benefit would result from work to introduce salinity tolerance to a line that already possessed it. He discussed the choice of hybrid parent with the company's breeders, tested selected lines for salinity tolerance and established that RV-2 was extremely susceptible to salinity. Since this parental line was known to produce hybrid seed with characteristics that were highly valued by the market, it was the clear choice for improvement. This choice of recipient was made jointly by Sulston (Biotechnology) and Borlaug (Breeding).

At the same time, the company needed to find a 'donor' for salinity tolerance—a line that carried this trait, and could be crossbred with RV-2 and then repeatedly back-crossed in order to produce progeny that had inherited salinity tolerance but in other respects were similar to RV-2. At an early stage, Borlaug decided that only cultivars would be considered as potential donors, not land-races nor wild relatives of rice, since an extended back-cross programme would be required to remove the undesirable characteristics of the latter kind of material. Furthermore, the donor would have to combine well with RV-2, and in particular to flower at the same time, so that pollination could be completed within the five-day period when the female parent is receptive.

Over a period of 3–4 months, the company's scientists searched for a donor that satisfied these criteria by collecting germplasm from several different institutes, as well as from some farmers' fields in places where they had contacts. In particular, an approach was made to the Rice Research Institute (RRI) (pseudonym used to maintain company confidentiality), a public-sector institute that was already working on salinity tolerance and had an established relationship with ACME. Discussions were complicated by the fact that India was introducing a new seed law: this would restrict the sharing of germplasm from national institutes with private industry (hitherto breeding materials had been shared freely with Indian companies), but the government had not yet provided guidelines to bring clarity to issues such as the royalties and other conditions for the provision of breeding materials, and the kinds of contract that should govern these transfers. One scientist interviewed suggested that at this stage ACME asked for breeders' lines containing the desired trait in a neutral genetic background, but that this request was declined because of these uncertainties about the changing intellectual property regime. Sulston, however, stated unequivocally that what he had asked for was a selection of cultivars, which is what was eventually provided. In any case, it seems clear that ACME and RRI knew and trusted each other and so were able to overcome any potential difficulties. Borlaug and Sulston were received by the RRI director, and following their discussions a formal agreement was made under which 12 possible donors were transferred to ACME. These lines were all salinity-tolerant high-yielding varieties that had already been released to farmers.

Among the lines transferred to ACME in this way was CSR1 (pseudonym used to maintain company confidentiality), the first high-yielding variety with high levels of salinity tolerance that had ever been released in India. Developed by the Central Soils Salinity Research Institute (CSSRI), it had been derived from pure line selections of local traditional cultivars found in the Sunderban areas of West Bengal by means of the pedigree and modified bulk pedigree method (Mishra *et al.*, 1997). While these lines were tall and late maturing, and so unpopular with farmers, they were hybridised with the high-yielding variety Jaya to produce a range of high-yielding, salt-tolerant cultivars, beginning with CSR1. This early-maturing dwarf variety, whose grain is short and bold with white rice and high amylose content, has a strong culm and so is not vulnerable to lodging. It had been released by India's Central Varietal Release Committee (CVRC) as early as 1989, and was the first released variety to be suitable for the conditions typically found in salt-affected irrigated rice fields: highly deteriorated alkaline (pH 9.8–10.2) and inland saline soil (ECe 6–11 dSm-1).

After receiving these breeding materials, Sulston screened the collection of possible donors for each of the components of salinity tolerance: alkaline resistance and tolerance of sodium and potassium salts. Furthermore, these materials were cultured *in vitro* in a saline solution, while a control was cultured in normal water, so that the development of each 'candidate donor' could be compared with that of the control. As Sulston explained, these tests had shown that 'CSR1' was 'the best donor', but it did suffer from certain disadvantages, the most serious of which was that in its then form it could not be used for hybrids 'because of restorer problems'.[5] Three possible donors were therefore considered, with the breeder making the final choice. At this point Borlaug decided to use 'CSR1', mainly because it showed excellent combining ability with the hybrid parent RV-2. A salt-tolerant line that had been developed by IRRI was considered but not used, because it combined poorly with RV-2 and because it did not produce grain with the characteristics required by consumers in south India.

The ensuing breeding programme depended on the use of molecular markers. Since the ACME laboratory does not establish new markers and has no plans to undertake such work, this breeding programme uses markers that were discovered elsewhere and in practice relies almost entirely on those that are in the public domain, held in databases that are freely accessible through the internet. However, this kind of data (the sequences that serve as markers for particular traits) is of limited value to ACME. Markers are established in particular populations (generally the progeny of a single cross) and are only known to be valid for members of that population. While they may well be valid in different populations, it is not possible to know *a priori* that this will be the case. The obvious solution would be for ACME to approach the organisation that 'tagged' the gene in question and to make use of breeding materials derived from the same population in which the marker had been established. In many cases, however, this approach is no longer feasible: the practice of free seed exchanges among breeders is in decline, and the fees that are charged for such seed samples are sometimes prohibitively high.

In practice, then, ACME uses the best breeding material that it can obtain. Since markers from the public domain may or may not be valid in such material, tests must be performed

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[5] The male parent of a hybrid crop must be able to restore fertility in the progeny of a male-sterile plant. Otherwise the F1 hybrid will also be infertile and so unable to produce grain to the farmers' satisfaction.

to find out which of the relevant markers will still work in these new backgrounds. This process of validation is essential, but is costly and time-consuming: eighty markers for salinity tolerance in rice had to be tested over an 18-month period in order to find just eight markers that would work in the company's breeding materials.[6] The company is now in the closing stages of validating the eight markers, while seeking and validating additional markers to improve the precision of the project.

3.2 The Role and Management of Breeders

Progress in this project is critically dependent on contributions from the breeding function. These include (but are not limited to) the tasks of choosing breeding lines, making a succession of crosses and caring for each generation of seedlings. These examples illustrate the collaborative nature of molecular breeding as an enterprise that is shared between breeders and biotechnologists. Plant breeding, however, has tended to be an individualistic profession, with breeders jealous of the credit for the valuable new crops that they develop and so wary of collaborative projects. Furthermore, within ACME the role of breeder was defined to include a range of other responsibilities, and there was little scope to delegate these tasks since the breeders' assistants were poorly educated and not trained to accept responsibility. As a result, it was difficult or impossible for Borlaug to make an adequate contribution to the salinity project as well as completing his other tasks.

The primary task of the breeder was to develop new products for ACME to market. A set of goals for this work was set by the management of the plant-breeding function, and the breeder was expected to meet these ambitious targets. And many breeding tasks must be performed at particular times: the rice plant only flowers for a short time each season, and so the work of pollination must be completed at this time. Since the work on salinity tolerance was shared between plant breeding and biotechnology, it was given lower priority than the 'real' breeding work and so tended to be left for later, particularly when urgent breeding tasks had to be completed.

Moreover, the role of breeder includes a number of activities that require time-consuming travel away from the breeding facility. When ACME's quality control tests revealed that there were problems with the purity of its rice hybrid, it was the rice breeder who had to visit the fields where rice-seed was produced (by farmers working under contract to ACME) in order to investigate the reasons for the problem. Furthermore, the breeder is expected to visit farmers in order to see the performance of the crops he had developed under a range of climatic conditions. As Borlaug stated in interview:

> I left twenty-two days before, for an all-India tour. I covered nearly five States and maybe 4000 km, almost half of India in distance. [Each day I attended] three meetings with farmers, talking with farmers, solving their problems and teaching them technological aspects... And also I found different climatic seasons, and I had to adjust my body and drinking water and so many things, constantly. I did twenty of these country days. (That is, his field trip lasted for three weeks.)

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[6] An additional difficulty was that only one of these public-domain markers for salinity tolerance was an SSR marker: the others were AFLP or RFLP. Since it is more expensive and technically demanding to use AFLP or RFLP markers, rather than SSR markers, to support a breeding programme, Sulston and his colleagues identified SSR markers that 'spanned' each of the loci tagged by these other markers, and then proceeded to validate each such SSR marker.

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On returning from one such tour in 2005, Borlaug found that the salinity project had suffered a reversal. The seedlings descended from his cross between CSR1 (the salt-tolerant donor) and RV-2B (the hybrid parent) had been exposed to a spell of unusually cold weather. Borlaug's assistant had not appreciated the importance of the material and so had failed to protect them from the cold. As a result, the seedlings died, setting back the project by about six months and demonstrating that the company did not have an adequate system for managing inputs from the breeding function.

At the very end of the period studied, the company recruited an additional two rice breeders with qualifications and experience at post-doctoral level, but also unveiled an ambitious programme to develop up to 50 new rice hybrids, meaning that all of the breeders would continue to be over-committed to projects within the breeding function. Nor were there any substantive changes to the breeders' role: one of the new recruits was initially appointed as Borlaug's deputy, making it possible to share the workload, but this individual soon persuaded the board to allow him to work independently, so that he could accept complete responsibility for his own projects and receive undivided credit for the success of any hybrids that he developed.

4 CONCLUSIONS

This account of an Indian company's experience of new product development using molecular breeding suggests a number of general lessons. The company's focus on hybrid rice, despite the fact that rice OPVs were initially far better at meeting the needs of their key market, made sense in commercial terms and so suggests that there is a continuing need for public-sector initiatives to meet this kind of societal need. At the same time, the very serious way in which the company worked to identify and satisfy the requirements of its customers demonstrates that private enterprise and the discipline of the market can produce a distinctive contribution to agricultural development.

The company's experiences in gaining access to molecular markers and to breeding materials stand in contrast to each other. It is perhaps surprising that even commercially valuable markers are generally placed in the public domain, so that ACME can simply download them from the internet and so benefit from the *de facto* common-property regime that governs most of the molecular markers that are relevant to plant breeding (Reece, 2006). However, the practical value of such markers is limited by the difficulty of gaining access to breeding materials in which they are known to work. These difficulties occur because breeding lines, including those in which markers are known to work, are now private property and so can only be used with the permission of their owners. Organisations that wish to use markers in their breeding programmes are therefore subject to considerable pressure to meet whatever financial or other conditions are set by the discoverer of the marker in return for germplasm in which it is known to function. ACME, however, could not accept the proposed conditions and so chose to invest time and resources in validating markers in whatever breeding materials were available locally.

ACME's difficulty in obtaining such breeding lines reflects the transition from a regime of Plant Breeders' Rights (PBRs as enshrined in the original agreement upon which the Union for the Protection of New Varieties of Plants (UPOV) was founded) to one that provides more patent-like forms of IP protection for such materials, so that they are becoming tradable commodities. While PBRs traditionally enabled breeders to charge a royalty when the varieties that they have developed are cultivated, they did not create property rights in the variety, which could therefore be freely used by rival breeders as an input into their breeding activities. However, the 1991 revision of the UPOV convention granted additional rights to breeders, so that their permission is now needed before materials they have produced can be used for further breeding. This change represents a convergence with the patent system, which also gives inventors a temporary monopoly on the use or further development of their inventions (Hughes and Deibel, 2006).

The breeding materials that ACME use were provided directly by the Indian public sector, although the international public sector (IRRI) had made a major contribution to the development of some of this material. These experiences underline the continuing importance of public investment in germplasm development in order to provide a basis for the private seed industry. Moreover, ACME gained access to breeding materials by using established relationships and mutual trust rather than market mechanisms: indeed, recent efforts to create property rights and hence a market in breeding materials merely hindered germplasm transfers. As in this case, access to germplasm is often negotiated by means of a complex range of strategies that rest on relationships of mutual trust between individual colleagues. Informal exchanges between breeders may, however, become less significant as breeding materials are increasingly subject to patent-like protection, meaning that their transfer and use will require the consent of the organisation that owns them. These changes may block socially desirable innovation, or at least increase the cost and reduce the efficiency of such initiatives, unless they are tempered by measures such as compulsory licensing at reasonable royalties when the public interest requires this.

ACME made effective use of the markers and breeding materials that it had obtained in these ways. It is clear that the plant breeders and biotechnologists appreciated the nature and value of each others' contributions to the joint project and so displayed a considerable degree of cognitive empathy (Haribabu, 2000). However, the rice breeder had a heavy workload, and so the decision to give priority to those projects for which the breeding function was solely responsible had an inevitable impact on the progress of shared projects. To some extent this situation resulted from the culture prevalent in the breeding function (but *not* the biotechnology laboratory), and probably more generally in the plant-breeding profession, which rewarded individual achievement and tended to discourage the sharing of responsibilities. The events that followed the appointment of a deputy rice breeder provide further evidence that this culture of individual achievement is deeply entrenched among plant breeders.

The limited progress made by the salinity-tolerance project reflects the priorities set by the management of the breeding function, which are perhaps surprising in view of the support given to this project by senior management. More fundamentally, it reflects the continuing value of plant-breeding skills and the gravity of the global shortage of breeders (Knight, 2003). While the company did eventually recruit more rice breeders, and made an attempt to change the way in which the role of breeder was defined, these responses are unlikely to address the problem. The company's ambitious plans to develop a large number of new rice hybrids are likely to take priority over other activities and mean that the workload of the breeders will continue to be heavy, while the apparent lack of rewards for shared achievement meant that efforts to redefine the role of breeder met with resistance and could not be implemented.

The events reported in this paper confirm that both the 'Fifth Generation' model and the 'Innovation Systems' framework are of value in highlighting key features of the process by which new products are developed. The immediate task is one of bringing together different kinds of specialised knowledge, reconfiguring them into a coherent whole and using them to solve the series of problems that innovation presents. This knowledge is embodied in people, notably in ACME's Plant Breeding and Biotechnology departments but also in Marketing and Production, as well as in germplasm, DNA sequences, and in other forms. The need to create organisational forms that facilitate collaboration between functions is an immediate consequence of the 'Fifth Generation' model, and is confirmed by ACME's experiences. However, ACME is set in a complicated institutional landscape, with its achievements being made possible by the effective linkages with national and international institutes that enabled it to receive indispensable inputs to its work. These linkages were modulated, both by the action of relevant institutions and by the effects of public policy. The most obvious of these was the introduction of IP in breeding lines, but underlying ACME's ability to form good working relationships with several public-sector research institutes was a longer-established policy to provide scientific support to the private sector. It is also significant that the project discussed was undertaken within a private company: while the public sector provided scientific and other support, it had the wrong institutional characteristics to undertake a project of this nature. The experiences reported here thus depended upon precisely those features of the situation that the 'innovation systems' framework highlights as being significant, and so confirm the value of this approach.

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