

Little application of molecular marker technology despite high investment.

The Food and Agriculture Organisation estimates that 842 million people were chronically undernourished in 1999/2001; the most recent period for which data is available. Of these people, 798 million lived in developing countries and 70 per cent relied on agriculture for their livelihoods, indicating that 560 million people whose livings are based on developing-country agriculture remain desperately poor. Many of those poor people could be helped by development of new crop varieties that meet their needs. Proponents of molecular marker technology claim that molecular markers are a useful tool for developing such crop varieties. The persistence of hunger demonstrates that this contribution has yet to be made.

Why is this?

The problem could lie in social institutions and the relationships between pure and applied science. These issues could be explored using the methods of social science, yet this area has attracted little or no attention from social scientists. Over a thousand papers discuss marker-assisted selection, yet just three articles on this topic are listed in the Social Sciences Citation Index. While a major technological development is taking place, there has been little or no exploration of its social consequences. This policy brief is therefore timely and unique.

What are molecular markers?

Molecular markers are identifiable DNA sequences, found at specific locations of the genome, and transmitted by the standard laws of inheritance from one generation to the next. They can be thought of as constant landmarks in the genome, since their presence (which can be detected by DNA assay) predicts the presence of the specific genes with which they are associated. From the point of view of a plant breeder, the presence of a particular marker in a sample of plant tissue predicts (with varying degrees of probability) that the trait associated with that marker will be present in the plant sampled and in its progeny. Now 'conventional' plant breeding methods revolve around three basic steps: generation of a population of plants having desirable traits; evaluation and selection of superior individuals; and recombination of the superior individuals to generate a new population for subsequent cycles of selection and improvement. Molecular markers can thus assist breeders in the process of evaluation and selection and so facilitate the production of improved new varieties. Their use is not controversial and does not impose requirements in terms of biosafety.

Limited impact of Marker Assisted Selection

It has been noted that while marker assisted selection has been available for fifteen years, the literature includes few or no reports of its use leading to released germplasm or varieties.

A review of UK research relevant to crop science prepared for the Biotechnology and Biological Sciences Research Council states bluntly that "there is little or no evidence to date that the high level of investment in plant science is having a significant impact on strategic and applied research in crop science."

Reasons for limited impact of marker assisted selection.

Inadequate links between pure science and applied science, in particular links between breeders and molecular biologists.

The BBSRC report explains the lack of impact partly in terms of inadequate communication between plant (pure) and crop (applied) scientists, and in terms of the knowledge from plant science not being "exploitable" by crop science.

The European Academies Science Advisory Council published a report in May 2004 criticising the fragmentation of European plant genomics research, warning against following the example of the UK, where "privatisation of plant breeding severed the emerging link between breeders and molecular geneticists." Instead, it argues that crop plant genomics will only stimulate innovation in agriculture if "a coherent EU strategy across the key scientific disciplines and linking to innovation policy is developed to unify hitherto fragmented research efforts."

Global decline in academic plant-breeding, with resources being transferred to molecular genetics and transgenic technologies.

The professionals who are needed to obtain practical benefit from advances in these technologies are no longer being trained in sufficient numbers. The shortage of plant breeders means that the potential contribution offered by molecular markers can only partially be realised.

Recommendation: More investment in plant breeding programmes and training.

Location of Research Institutes.

Discovery of molecular markers: centralised

The high cost of molecular marker discovery imposes an unavoidable pressure for centralisation (to capture economies of scale,) because the process requires expert scientific management and high cost equipment. Each such facility could serve breeding programmes throughout the world, so long as each 'client' breeding programme was equipped with the infrastructure necessary for electronic communication and for analysing and interpreting DNA sequence data.

Breeding and application: dispersed

The diversity of circumstances and agro-environments cultivated by poor farmers means that they require a diverse and decentralised research and plant breeding system. The objectives of any breeding programme should be informed by the characteristics preferred by the farmers who are intended to grow the crop varieties that the programme will produce. Conversations between farmers and breeders can take place more easily if the breeding programme is based near to the farms of its clients.

Good links between the two.

In view of the high cost of marker discovery, molecular marker researchers must maintain close links with plant breeders throughout the world, in order to ensure that the markers that they discover are for traits that are indeed of practical importance and are available in breeding

lines that show good combining ability with elite cultivars.

Recommendation: Centrally sited genomic research institutes must service locally based plant breeding programmes with good links to farmers. Models of communication should be bottom up ensuring that all work is guided by an appreciation of user needs. Additional funding is required for staff training and equipment to enable marker assisted selection in local plant breeding programmes.

Management of social processes: integrating the contributions of specialists from different disciplines.

Professionals may be reluctant to share the knowledge that constitutes their most precious asset. Many professionals have little respect for those outside their field, even when all parties are supposedly seeking the same goal, and so are reluctant to learn from people outside their own profession.

The discovery and use of valuable markers requires productive collaboration between scientists trained in molecular biology on the one hand, and applied sciences like plant breeding and genetics, pathology and entomology on the other. Since practitioners of each of these specialisms constitute distinct communities, deliberate efforts are required to integrate their work into a coherent whole. Effective leadership is required both to bridge the gap between the disciplines that are involved and to overcome the additional barriers created by scientists working in different institutions and cultures. Perhaps the primary task is that of building trust between the various researchers involved. Achieving this requires a commitment to spend a reasonable amount of time together.

Recommendation: Research organisations need to work in ways that promote collaboration.

Example of best practise: The Rockefeller Foundation in India

As part of the Rockefeller International Program on Rice Biotechnology, rice-breeders became familiar with molecular technology through a range of training opportunities, including doctoral and post-doctoral programs. Both rice breeders and molecular biologists received training in the advanced laboratories of the UK, the USA, and at the International Rice Research Institute in the Philippines. Scientists engaged in rice molecular biology and biotechnology formed the National Rice Biotechnology Network (NRBN) to facilitate collaboration. Annual meetings of the NRBN provided opportunities to exchange ideas and research findings. It brought together scientists with different disciplinary backgrounds, including plant breeding, molecular biology, pathology and entomology. It thus went some way towards creating the conditions necessary for the emergence of trans-disciplinary teams deploying molecular methods to undertake research on rice.

Two of the research groups that had been supported by the Rockefeller Foundation, one in the Centre for Cellular and Molecular Biology and the other in the Directorate of Rice Research collaborated in a project that used marker-assisted selection to introduce resistance to the disease Bacterial Leaf Blight (BLB) into a popular rice cultivar. The project involved introgressing three genes that confer resistance against BLB into the genetic background of Samba Mashuri, a rice cultivar that is highly popular in South India. It made use of the rice line SS1113, into which the three genes had already been pyramided. By 2005 the early stages of this project had been successfully completed, and at the time of writing the disease-resistant Samba Mashuri was undergoing field trials.

Interviews revealed that the members of the two research groups understood the value of each other's expertise and what each could expect of the other. The group at the Centre for Cellular and Molecular Biology had expertise in molecular biology while the group at the Directorate of Rice Research had strengths in rice breeding and multi-location field testing and validation. There was thus a natural division of labour between the two groups, representing a convergence between the lab-based culture of molecular biologists and the field-based culture of plant breeders. The progress made by these groups demonstrates that the use of molecular methods offers real practical benefits so long as it is appropriately organised and managed.

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