biotechnology commission

Agriculture and Environment
Biotechnology Commission

What shapes the research agenda?
in agricultural biotechnology

A report by the Agriculture and Environment Biotechnology Commission (AEBC)

Plant breeding case study

April 2005

Context of the study

1. Summary The consultation and information gathering modules of the Agriculture and Environment Biotechnology Commission's (AEBC's) workstream on *What Shapes the Research Agenda?* [6] have identified a number of key drivers of agricultural biotechnology research and thrown up a number of issues around the processes through which research agendas are determined. This case study aims to focus on one area of research in order to identify the important influences on that field, and explore the implication of these drivers for the research agenda.

2. Plant breeding was an area of research identified for such a case study early on in the Commission's thinking, and a number of consultation respondents also highlighted some of the issues relevant to plant breeding[7]. This has been a field where there have been significant changes in the structure and nature of research over the past 50 years, and these can be associated with changes in Government policy, technology developments, and public views.

3. This study does not aim to provide a comprehensive review of research in the field of plant breeding, but is based on desk research using existing reports and academic papers, and discussions with a range of plant breeders and academics in the field[8]. It draws heavily on, and endorses much of, the work of the BBSRC Crop Science Review[9] and the Defra-commissioned project on future public research investment in crop genetic improvement[10].

4. This case study has looked at changes to the structure and nature of plant breeding research in the UK, and the reasons behind this. It is possible to see that all the drivers identified by the AEBC in our broader information gathering and analysis[11] have had an influence on the agenda.

5. Technological developments have made it possible for significant advances to be made to the rate and nature of crop improvements. However, in the UK this

1 AEBC (2005) *What shapes the research agenda in agricultural biotechnology?* **URN: 05/1078.** For electronic copies of this final report and the five modules that contributed to it, go to www.aebc.gov.uk and click on "Reports". Hard copies are available by calling the DTI publications Orderline on 0845 015 0010 and quoting the Unique Reference Number (URN) code for the paper wanted.
2 AEBC (2005) *What shapes the research agenda? Analysis of responses to written consultation* **URN: 05/1083**
3 A list of those who have provided input into this study is provided at Annex 1.
4 BBSRC (2004) *Review of BBSRC-funded research relevant crop science: A report for BBSRC council*
5 ADAS and Biohybrids Ltd (2002) *The role of future public research investment in the genetic improvement of UK grown crops*
6 AEBC (2005) *What shapes the research agenda in agricultural biotechnology?* **URN: 05/1078.** For electronic copies of this final report and the five modules that contributed to it, go to www.aebc.gov.uk and click on "Reports". Hard copies are available by calling the DTI publications Orderline on 0845 015 0010 and quoting the Unique Reference Number (URN) code for the paper wanted.
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11 AEBC (2005) *What shapes the research agenda? Information and Analysis Paper* **URN: 05/1082**

technological drive has been tempered by slow uptake of new technology by industrial breeders, and negative public reaction to biotechnologies.

6. Policy decisions to move out of near market research in the 1980s, and the sale of the Plant Breeding Institute (PBI) have catalysed a shift of plant breeding research from the public to the private sector.

7. Plant breeding has also responded to shifts in priorities in the farming industry partly driven by changing Government agricultural and trade policies. However, with a large proportion of breeding now in the private sector, market forces are having increasing influence on the research agenda.

8. Although a number of positive changes have resulted from these developments, this paper concludes that there is now a risk that plant breeding research objectives will be overly focused on purely economic goals, at the expense of social and environmental objectives. A role for Government therefore emerges in providing research to fill any potential gaps, as well as incentivising the market to encourage industry to undertake research relevant to sustainability goals. The importance of engaging with the public and stakeholders at an early stage of technology is also highlighted.

Introduction to plant breeding

9. Plant breeding aims to improve crop performance and/or quality through the development of new varieties. The origins of plant breeding go back thousands of years to primitive farmers who selected the best plants in one year to provide seed for their next crop. This selective breeding allowed refinement of the natural evolutionary processes to produce plants more suited to the needs of farmers and consumers.

10. It was not until the early 20th century that enough was known to be able to select and manipulate plants in a more scientific way. Today, a range of sophisticated, high investment technologies are available, although in the UK these have not been widely taken up and some, especially genetic modification (GM), have proved controversial.

11. Plant breeding research is a long-term activity. Developing a new cereal variety can take around seven to twelve years from the first cross to the variety coming into the marketplace. It is even longer for some other crops, such as potatoes and trees. As well as developing new varieties, plant breeders also need to maintain the genetic purity of existing lines and pre-commercial seed to maintain the quality and performance of each variety. The cost of maintaining a typical (large) wheat-breeding programme is estimated at £1.5 million per year.[12]

12. Plant breeding also relies on maintaining a diverse gene pool on which to draw, and the first gene banks were created in the 19th century. The applied work of breeders also draws on many aspects of basic scientific research, including studies

12 BSPB *Plant breeding – the business and science of crop improvement*

to help understand the ways in which plants grow, use water or are affected by diseases, for example.

13. Until the 1960s, plant breeding was largely a public sector activity in the UK, but today the majority of breeding is carried out by a small number of private companies, many European owned, including farmers' cooperatives like Limagrain[13].

Influences on plant breeding research

14. There have been a number of changes to plant breeding over the years and an attempt to identify some of the influencing factors behind these is provided below.

Advances in knowledge and technology

15. Plant breeding has moved on significantly from that carried out by early farmers. Dutch botanist Hugo de Vries's rediscovery of Mendel's laws of inheritance, his development of mutation theory, and Watson and Crick's elucidation of the structure of DNA, leading rapidly to the development of modern genetic technologies, provided two major advances in genetics. These advances, along with increased understanding of pollination and plant reproduction have provided breeders with a host of new technological tools. Breeders now essentially aim to increase genetic gain per unit time. The rate of genetic gain is determined by the selection pressure applied (the difference between the mean of the selected individuals and the mean of the entire, original population), how well the character under selection is inherited from generation to generation (the heritability), and the number of generations of selection that can be made per year (the more generations per year the higher the rate of gain). Therefore techniques that influence these factors are valuable to breeders. These include protoplast fusion, embryo rescue and assisted pollination, double haploid breeding, and the use of genomics, proteomics and genetic modification.

16. Through the 1970s to the 1990s the large agrochemical companies were keen to capitalise on the advances in biotechnology, especially GM. Some invested heavily in their technology base and some also bought into the seed market as a route to the technology. Plant breeding was one important area of their portfolios that made use of the new technology.

17. In the public sector, there was also a 'technology push' to complement the 'technology pull' from industry with an increasing emphasis on biotechnology. This was reflected for example by the establishment of the Biotechnology and Biological Sciences Research Council (BBSRC) from the Agriculture and Food Research Council (and parts of the Science and Engineering Research Council) in 1994.

18. Therefore, technology has been a significant driver in research in plant breeding, especially for the large multinational companies. However, in the UK today, it is

13 See Annex 3 for a table of major crop breeders

evident that much plant breeding still relies on conventional means with limited use of the new technologies.

Public opinion

19. Although there are few issues of societal concern that are specific to plant breeding *per se*, there has been negative public reaction in the UK and Europe to agricultural biotechnology involving GM crops. This lack of public confidence in crop development is affected not only by concerns about the technology itself, but also the shift from public to private funding for research in this area, with many of the arguments against GM technologies tied in with the issues around commercial influence and globalisation.

20. Public hostility, and its extreme manifestation in the vandalising of GM crop trials, for example, has affected the nature of the research carried out in UK public institutes, and companies' decisions to withdraw from research in the UK, with a concomitant loss of jobs and infrastructure.

Government policies

21. Plant breeding has changed over the years as the agricultural industry itself has changed. Farmers are the customers of the industry and therefore the industry is responsive to the changing pressures and demands of agriculture. For example, the food shortages after the second world war meant that agricultural research in the UK was focused on domestic production and food security. Plant breeding contributed significantly (along with greater mechanisation, agrochemical usage and other factors) to the increases in agricultural productivity achieved over the last 50 years. For example, from 1947 to 1992, wheat yields in the UK increased three-fold and around half of this increase can be attributed to plant breeding[14].

22. By the 1970s and 1980s, the UK Government and European agricultural subsidy-based policies had led to overproduction and food surpluses, calling into question the need for research to increase production.

23. Through the 1980s and 1990s plant breeding was affected by the UK Government's shift away from 'near-market' research. In the 1980s the Government's emphasis on value for money in public spending meant that Government Department research moved away from applied work that benefited the private sector directly. As a result, many assets were transferred from the public to the private sector. Then in 1990, the Priorities Board for Research and Development in Agriculture and Food recommended complete withdrawal from near-market agricultural research, representing around £30m of the Ministry of Agriculture Fisheries and Food (MAFF) budget. The *Realising our Potential* White Paper followed in 1993 and placed a strong emphasis on wealth creation through science.[15]

14 BSPB *Plant breeding – the business and science of crop improvement*
15 For further details, see: AEBC (2005) *What shapes the research agenda? Information and Analysis Paper*
URN: 05/1082

24. These changes had major implications for plant breeding, which is essentially applied near-market research. The most significant change in this respect was the sale in 1987 of the MAFF National Seed Development Organisation and a large part of the AFRC Plant Breeding Institute to Unilever, to create the Plant Breeding International Corporation (PBIC).

25. In more recent years, Government policy for agriculture has shifted towards an agenda of sustainability, encompassing economic, social and environmental objectives. Government research is also responding to wider societal concerns such as food safety. However, at the same time farming has become a less profitable industry and farmers are increasingly operating in a more competitive global market, under liberalized trade rules. This means increasing pressures from international policy decisions such as the enlargement of the EU, the 'Everything but Arms' Agreement and continuing negotiations under the Doha trade talks.

26. We have found farmers, the seed industry and therefore breeders are still largely focused on yield and quality, and 'high input-high output' varieties. Given the lengthy breeding cycles it inevitably takes time for any shift to more environmental goals to take effect.

Characterisation of the industry

Who does plant breeding in the UK?

27. There has been a significant shift in breeding from the public to the private sector over approximately the last 50 years. The majority of breeders in this country are registered with the British Society of Plant Breeders (BSPB), whose current membership suggests there are 52 breeding organisations operating in the UK. Of these, only three are in the public sector.

28. In the public sector, breeding only really occurs in a few institutes. The Scottish Crop Research Institute (SCRI) breeds potatoes, kale and soft fruits such as raspberries and loganberries. The Institute of Environmental and Grassland Research (IGER) breeds oats in a private-public partnership with SW Seed. It also breeds grasses and forage legumes to 'finished variety' where multiplication and commercialisation is carried out through a partnership with Germinal Holdings. The John Innes Centre (JIC) has a strong plant science base and although its work is mostly basic and strategic, it has worked in partnership with breeding companies such as DuPont and Syngenta in particular areas of science.[16] East Malling Research (EMR)[17]breeds fruit, hops, timber and woody ornamentals, and Horticulture Research International[18] carries out a large amount of work on vegetables, flowers and glasshouse crops (although since its transfer to the University of Warwick we do not have up to date information on this).

29. Defra also sponsors some plant breeding research and in the period 2001/2-2003/4 spent around £18 million. This included some 104 projects[19], ranging from basic

16 Information from James Reeves, NIAB, January 2005
17 EMR is a limited company and also a charity with significant funding from Defra
18 Formerly the National Vegetable Research Station
19 Response from Ben Bradshaw to Parliamentary Question 231103/04 from Dr Gavin Strang, 25 March 2004

research to more applied work, and activities under the new crop genetic improvement networks.[20] Crop breeding is also mentioned as an important part of SEERAD's new science strategy programme 'Profitable and sustainable agriculture – plants'.[21]

30. Private sector breeding began to flourish in the UK with the introduction of the Plant Varieties and Seeds Act in 1964, which established a system of royalty payments on seeds, thereby providing a means of protection and return for breeders' efforts. Today in the UK, most breeding of agricultural crops is carried out by the private sector.

31. However, plant breeding is not highly profitable with the total royalty values for all UK crops approximately €50-55 million per year[22]. The breeding industry is a small part of the food supply chain and value is realised further down the chain. The UK market is small and the number of breeders is decreasing. The industry has been affected by challenges such as continued reduction in volume of certified seeds, reduction in average seeding rate, farmers using farm-saved seed, regulatory and legislation pressures, and Europe's negative reaction to GM technology.[23]

32. The agricultural levy bodies in the UK also play a role in plant breeding, although their spend on research is fairly small – in total around £8 million in 2001-02 (a table showing breakdown of spend is in Annex B). Additionally, they sponsor some work in collaboration with other researchers - for example the Home Grown Cereals Authority (HGCA) has supported the work of JIC through a personal fellowship[24], and the British Beet Research Organisation (BBRO) is building links with the multinational breeding companies to develop the new genetic traits from the Broom's Barn Experimental Research Station.[25]

33. It should be noted however that it is difficult to discuss 'plant breeding' in general as there are many differences to the structure of the industry depending on which crops are considered. For crops that do not 'travel' well, the majority are still bred by UK-based companies. For example, in 2003-04, 97.7% of winter wheat and 99% of spring barley certified seed sales were of varieties bred in the UK.[26] However, for oats there is only one breeder in the UK, and for oilseed rape and sugar beet, the majority of breeders are based on the continent.[27] Varieties are tested in the UK and companies work through seed agents based in the UK (many of which are also arms of multinational companies). A table showing the breeders of the main UK crops is shown in Annex 3, although it should be noted that not all of these companies carry out their research and breeding activities in the UK.

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20 The crops for which such networks are being established are wheat, oilseed rape, oats, pulse crops, short rotation coppice, and miscanthus.
21 SEERAD (2005) *Strategic Research for SEERAD 2005-2010: environment, biology and agriculture*
22 Laurie S. (BBSRC) (2005) *The landscape of plant genomics in the UK.* Information gathered as part of the ERAnet in plant genomics
23 Information from Penny Maplestone, BSPB, February 2005
24 ADAS and Biohybrids Ltd (2002) *The role of future public research investment in the genetic improvement of UK grown crops*
25 Information from John Macleod, BBRO, January 2005
26 Information from Penny Maplestone, BSPB, February 2005
27 Information from James Reeves, NIAB, January 2005

The case of the PBI

34. The shift from public to private sector plant breeding activity in the UK is characterised by the history of the Plant Breeding Institute (PBI). Its sale had a significant impact on plant breeding, especially in cereals. PBI was established in 1912 as a Cambridge University plant breeding institute by the Board of Agriculture. In 1954 a new PBI site opened which was independent of the University. Public sector plant breeding also took place in the Welsh Plant Breeding Station (grass and forage), the National Vegetable Research Station (vegetables) and the Scottish Plant Breeding Station (potatoes, forage and barley).[28]

35. In 1986, PBI received funding of around £3m in total, from the Ministry for Education and Science for fundamental work, and from MAFF for commissioned breeding work and work allied to breeding. An additional £1.5 m financial support for research projects came from various commercial firms (e.g. Imperial Chemical Industries Limited, Dupont de Nemours International SA). The Institute had a research staff of 166 in a total complement of 245.[29]

36. Plant varieties developed by PBI were distributed to seed producers and merchants through the government-owned National Seed Development Organisation (NSDO). They multiplied basic seed and collected royalties on seed and around 70-80% of their income was dependent on varieties from PBI.[30] PBI was highly successful and dominated UK plant breeding in a number of crops - approximately 90% of wheat grown in the UK was from varieties bred at PBI.[31]

37. As part of the emphasis on value for money, PBI was one of the Government assets transferred to the private sector. In 1987 PBI was sold with NSDO to Unilever (who subsequently sold it to Monsanto). In 1990, the applied and basic scientists were split, with the fundamental scientists moving to the John Innes site to form the 'Cambridge Laboratory' whilst most of the applied scientists transferred to the new PBIC.

38. In 1994 the Cambridge Laboratory was subsumed in the creation of the JIC (along with the Nitrogen Fixation Institute and the John Innes Institute). Monsanto have since sold off several of the crop programmes to other companies, and retain only a small oilseed rape programme which was based at the original PBI. Cereals breeding continues on site with RAGT.

39. There have also been a number of changes to the structure of the plant breeding stations in the Devolved Administrations, with the formation of the SCRI from the Scottish Plant Breeding Station and the Scottish Horticultural Research Institute; and IGER from sites of the Welsh Plant Breeding Station and the Institute of Grassland and Animal Production. However, the privatisation model was not adopted in the same way, and in Scotland a public-private partnership model was

28 Information from the websites of the John Innes Centre www.jic.bbsrc.ac.uk , Institute of Grassland and Environmental Research www.iger.bbsrc.ac.uk and the Scottish Crop Research Institute www.scri.sari.ac.uk.
29 Antoine R. (1986) *Report on a visit to Europe by the Chairman of the Food and Agricultural Research Council (Mauritius)* http://farc.gov.mu/ra.htm
30 Pray C.E. (1996) *Impact of privatising agricultural research in Great Britain: an interim report on PBI and ADAS,* Food Policy 21(3), 305-318
31 Information from British Wheat Breeders, February 2005

advocated. (For example SCRI established a commercial arm: Mylnefield Research Services Ltd[32].)

Consequences of the drivers and structural changes in plant breeding

40. The current system has a number of strengths, including that the industry is seen as leaner, more dynamic and flexible than before, and breeders are more closely aligned with market demands. Wheat breeders feel their industry has reached its natural, appropriate size. Furthermore, some feel the Plant Breeders' Rights (PBR) system has encouraged innovation through increased competitiveness. PBR also ensures breeders have access to germplasm of protected varieties as breeders' rights do not extend to i) acts done privately and for non-commercial purposes, ii) acts done for experimental purposes, and iii) acts done for the purpose of breeding other varieties[33]. There is also a farmers' privilege in the UK, which allows farmers to save seeds and only pay approximately half of the royalty.

41. However, many of those we spoke to have highlighted a number of problems or potential future problems with plant breeding research. With an understanding of the drivers of the plant breeding agenda, and the changes in research structure that have occurred, it is possible to suggest contributing factors behind these problems.

Weak links between applied and basic research

42. Many have suggested that there is now a split between applied and basic research.[34] Many of those we spoke to considered that PBI had benefited from the collocation of basic plant scientists and more applied researchers before privatisation,[35] and that the split of scientists when PBI was sold fragmented the research base. However, others who worked at PBI at the time have suggested that in some ways the basic and applied sciences were not well aligned even then, and much of its commercial success was due to certain individuals who were keen to breed commercial varieties of wheat[36].

Links between the public and private sector need to be strengthened

43. Government science policy has focused public sector responsibilities on fundamental science and strongly discouraged 'near-market' work, leaving this to the private sector[37]. This means that not only do links need to be actively made between basic and applied work, but also between the public and the private sectors. This poses potential issues regarding the cultural, physical and institutional barriers that may exist between scientists in the different sectors, which may have an inhibitory influence on information sharing.

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32 Information from Gavin Ramsay, SCRI, January 2005

33Further details on the UPOV system of plant variety protection can be found at http://www.upov.int/en/about/upov_system.htm#what_is_a_pv

34 Information from the British Wheat Breeders, NIAB, Gavin Ramsay, John Macleod, January 2005. The BBSRC also recently called for basic plant science and applied crop science to be brought closer together. See BBSRC (2004) *Review of BBSRC-funded research relevant crop science: A report for BBSRC council*

35 See also Webster A.J. (1989) *Privatisation of public sector research: the case of a plant breeding institute,* Science and Public Policy, 16(4), 224-232

36 Information from the British Wheat Breeders, February 2005

37 Today 89% of Government funding on plant genetic improvement is on basic research, 11% applied. Data from NIAB (2005) *UK crop genetic improvement – a new role for NIAB*

44. Furthermore, the research culture in the UK has traditional strengths in and encourages fundamental science, but is less good at exploiting that knowledge[38]. Some have also suggested that the research evaluation systems, such as the Research Assessment Exercise (RAE), are not conducive to research of an applied nature[39]. The Government's cross-cutting review of science and research also recommended that steps were taken to ensure the RAE system does not discriminate against applied research, interdisciplinary work, and secondments to industry[40]. Therefore, there may be inherent structural issues in the research system that act as a barrier to technology transfer.

45. These factors may create a gap in research that falls between the public and private sectors. A report for Defra on future public support for plant breeding[41] suggested that there is a 'middle ground' of research that is not being carried out in areas such as identifying sources of genetic variation for sustainability traits, pre-breeding (material suitable for inclusion in commercial programmes) and crop design (for some particular crops). This could particularly hinder smaller companies as they cannot afford to support long-term basic research programmes, and are reluctant or unable to pick up some new technologies due to the associated risks, costs and any public hostility[42].

46. Industry will of course seek opportunities to form links with the public sector and build on areas of basic research where they can see the benefits. End users (in the private sector) who will benefit from use of the research should also take some responsibility for pursuing research to meet their aims as there are of course limits to what the public sector could and should fund. This system seems to be working fairly effectively at present – for example there are a number of LINK projects in place and new Defra Genetic Improvement Networks (GINs) have been established.

47. However, there may be issues for crops where commercial returns do not justify the scientific investment. Furthermore, the major breakthroughs in research (e.g. semi-dwarf varieties) have often come from the public sector, and varieties such as Maris Piper potatoes were developed by PBI and are still significant in today's market. The wheat breeders we spoke to acknowledge they are still reaping the benefits of the work done at PBI (there have only been two breeding cycles in wheat since PBI was privatised)[43]. Therefore it seems there is a role for continued public sector investment in this area. Note though breeders would want to ensure this was done in such a way that the public sector did not compete with industry, as was felt to be the case with PBI.

Fewer breeding programmes

38 For example, the DTI Innovation report notes that, overall, the UK's innovation performance (defined as the successful exploitation of new ideas) is 'not good enough'. DTI (2003) *Innovation report – Competing in a global economy: the innovation challenge.*
39 Information from NIAB and John Macleod, January 2005.
40 HMT/DFES/OST/DTI (2002) *Cross cutting review of science and research: Final report*
41 ADAS and Biohybrids Ltd (2002) *The role of future public research investment in the genetic improvement of UK grown crops*
42 Information from NIAB, Chris Leaver, British Wheat Breeders, February 2005
43 Information from British Wheat Breeders, February 2005

48. The worsening economic position of agriculture, increasing pressures on the industry, and a number of mergers and acquisitions have affected plant breeders. In the UK and Europe, public hostility to biotechnology has also had an effect and the number of breeders has decreased.

49. This has contributed to a **risk of losing research for the benefit of the UK.** Plant breeding is increasingly concentrated in the private sector, and many firms operating in the UK are based elsewhere in Europe. This means that their breeding programmes cover a wide range of countries and the needs of the UK may get marginalised as it is a relatively small market with limited profit-making potential[44]. This does not seem to be a significant issue at the moment, and breeding crops on the continent is not necessarily a problem. Some crops 'travel well', others cannot be bred in this country, and varieties are tested when entered into trials for the UK. However, some of those we have spoken to raised concerns over specific crops (such as legumes and horticultural crops), new varieties of which would be beneficial to UK growers but where research is limited. There are also certain traits which would be particularly useful in a UK environment, but are not being researched fully (such as drought resistance in sugar beet, which may also have environmental advantages). In an extreme scenario, it is possible to envisage that some crops will cease to be improved for growing in the UK, or perhaps more likely, that crops that are less well adapted to UK conditions will be sold in the UK.

Refocus on private sector objectives

50. As is to be expected, the private sector's aims for plant breeding are strongly aligned to commercial objectives, which has some important implications.

51. **Research on sustainability objectives is limited.** The industry today cannot afford to undertake work that has purely environmental or social benefits, if there is no economic incentive and there is little market demand. This means an increasing risk of divergence between the objectives of breeders and those of Government, which are more environmental rather than production based. Some are also concerned that research into crops with e.g. health and nutritional benefits is limited[45], although globally there are companies conducting some research in these areas.

52. **Potential 'orphan crops'.** Industry tends to focus on the main commodity crops, and the newer crops or minority crops (e.g. durum wheat, linseed) are unlikely to be funded until there is a market for them[46]. There is also currently a lack of activity in the public sector. Such crops could have potential environmental or social benefits e.g. non-food crop development for energy or health purposes.

53. **Potential lack of UK plant breeding research for developing countries.** Many feel that the private sector in the UK is not likely to focus sufficiently on work that is directly relevant to the needs of developing countries as it unlikely to be highly

44 Information from NIAB and John Macleod, January 2005. See also Webster A.J. (1989) *Privatisation of public sector research: the case of a plant breeding institute,* Science and Public Policy, 16(4), 224-232

45 Information from FARM, February 2005

46 It has also been suggested by FARM that the focus on the main commodity crops has increased since privatisation of PBI.

profitable. Others from industry point out that some work is carried out in the private sector towards these objectives.

54. The public sector in the UK also conducts limited work in this area and it has been suggested that research into plant breeding for developing countries has decreased over the years due to policy decisions which focused more on UK needs[47]. There is currently a DFID plant sciences research programme with a significant plant breeding component, based in Bangor, which is due to complete its work in 2006. DFID will be commissioning new programmes that build on the success of this and other DFID agricultural research programmes for developing countries. A recent Science and Technology select committee report[48] highlighted some general problems with science for less developed countries (e.g. the lack of lead department and lack of coordination) and these are undoubtedly also relevant to plant breeding. Slow uptake or rejection of new marketed varieties has been said to have led to more participatory models of plant breeding and varietal selection, working with farmers and researchers in developing countries, but it has also been suggested that more work needs to be done on identifying the needs of developing countries[49]. Some studies have noted that, after the privatisation of PBI, there was a decrease in willingness to collaborate with other breeders, especially in less developed countries.[50] We have been told that this is a matter of individual company policy, and some companies share data freely.[51] It should also be noted that there are a number of international organisations conducting agricultural research for developing countries, such as CGIAR, UK support for which has recently increased significantly.

55. **Greater focus on technologies that potentially conflict with social objectives.** It will be in a company's interests to pursue technologies that protect their research investments and ensure long-term income. Development of such technologies has often proved controversial, for example, Genetic Use Restriction Technologies (GURTs) or 'terminator technologies', which have been criticised as disadvantaging poor farmers. Conversely, there will be little impetus to develop technologies that may have benefits for farmers and consumers, but show limited profit-making potential for the breeders.

Lack of training opportunities

56. Due to Government policy decisions to pull out of research in this area and the sale of PBI, several of those we spoke to expressed a concern that there are now very few places to train plant breeders in the public sector in the UK[52]. This is a serious issue for maintaining the scientific skills base in this country, especially as there are some concerns that international breeding companies may cease to meet the needs of the UK in the future (see paragraph 50 above). Given the restricted

47 Information from John Witcombe, Manager of DFID Plant Sciences Research Programme, February 2005. See also discussions with Ian Crute (Director of Rothamsted) at AEBC meeting May 2004. Minutes available at http://www2.aebc.gov.uk/aebc/meetings/meetings_050504_minutes.shtml

48 House of Commons Science and Technology Committee (2004) *Thirteenth report of session 2003-4: the use of science in UK international development policy*

49 Information from FARM, February 2005

50 Webster A.J. (1989) *Privatisation of public sector research: the case of a plant breeding institute,* Science and Public Policy, 16(4), 224-232

51 Information from BSPB and British Wheat Breeders, February 2005

52 Information from British Wheat Breeders, John Macleod, BBRO and Chris Leaver, Oxford University Plant Sciences Department, February 2005

range of breeding undertaken in the public sector, there is also a question around whether it has the capacity to provide the full range of plant breeding training required. Therefore there is a potential role for the private sector also to provide some training.

Issues over Plant Breeders Rights

57. Several of those we have spoken to have mentioned that policy interventions on intellectual property (both at a national level through the introduction of the Plant Variety and Seeds Act in 1964, and the international UPOV convention) have had a significant impact on the industry.

58. Plant breeders' rights (PBR) are used by both public and private sector breeders, and some feel that, as with the patent system, this may provide a push towards plant breeding in the private rather than public sector. Some are wary that the system may inhibit information sharing, especially due to commercial secrecy in the development stages of breeding. Others in the industry maintain that there is good exchange of germplasm and this is recognised to be important by all in the market. As described previously, there is also a 'breeders' exemption' which ensures access to genetic material once a variety is produced, without infringing the PBR. BSPB supports the breeders' exemption, but feels that in other areas of the legislative framework, notably farm saved seeds, there is not an appropriate balance between the holder of the PBR and the user of the protected material[53].

59. It is evident that there are cultural differences in the way the public and private sectors handle their intellectual property, and this can lead to frustration and a potential barrier to information sharing. Concerns have also been expressed over the patenting of genes and gene functions, although these issues are not specific to plant breeding, and their in-depth consideration is beyond the realms of this study.

Conclusions - Lessons for future plant breeding research in the UK

Public sector support for plant breeding research

60. In order for any public sector plant breeding research to impact on farmers and consumers, it has to filter through the comparatively small plant breeding industry. A healthy industry therefore is beneficial to farmers, consumers and the economy. Knowledge transfer and the application of basic science done in the public sector will be needed to achieve this.

61. As with most research, commercial returns from private sector plant breeding research will be low (due, for example, to the risks involved, and the likelihood that other companies will benefit from one company's investments). As a result the sector is likely to under-provide research[54]. **The public sector therefore has a role in supporting the industry, particularly with respect to providing the long-term underpinning plant research required.**

53 Maplestone P. (BSPB), letter to SEERAD on "SEERAD Research Strategy Review: Consultation on draft research strategy", dated 2 August 2004

54 ADAS and Biohybrids Ltd (2002) *The role of future public research investment in the genetic improvement of UK grown crops*

62. There also appears to be a **re-emerging role for the public sector in the realm of what is deemed to be 'near-market'**. Defra is carrying out a number of plant breeding projects in this applied area, and the establishment of their crop genetic improvement networks (GINs) is likely to be helpful in this. Although it is too early to evaluate, Defra feels that the GINs have catalysed a reappraisal of the roles and relationship of the public and private sectors[55].

63. **The public sector will need to undertake research to a more commercially applicable stage for crops where there is little or no market demand currently, but where it would be environmentally or socially beneficial to encourage one. For example, this may include developing new environmentally friendly varieties, energy crops and break crops.** The public sector also needs to conduct more holistic process-based (as opposed to product focused) research. The social, environmental and economic effects of the products of plant breeding will be based not only on the products themselves, but also the manner in which they are used.

64. This research also needs to **ensure it meet the needs of those *smaller* UK based companies** whose interests may not be represented in the main Government initiatives such as the LINK projects, and whose research needs are likely to differ from those of large multinationals[56].

65. Lack of knowledge will affect both demand and supply – if breeders are unaware of technical possibilities they will not maximise these, and if farmers are unaware of the performance characteristics of new varieties they will not adopt them.[57] The public sector therefore needs to share its research as openly as possible, and facilitate uptake by the private sector. Government seems to have recognised this, with Defra[58], SEERAD[59], BBSRC[60] and NIAB[61] proposing action to support the plant breeding industry and address gaps in public good research. This requires action to **build on consultation with farmers and breeders, knowledge transfer activities, collaborative ventures, information sharing, and innovative ways of contracting research**[62]. In some respects, the participative models now used in developing countries' breeding programmes could be used as a starting point for developing such approaches.

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55 Information from Donal Murphy-Bokern, Defra, February 2005

56 A Defra-commissioned report suggested that small breeders sought investment in germplasm improvement and introduction of novel variation into useful backgrounds, whereas larger companies felt they could exploit more basic science. ADAS and Biohybrids Ltd (2002) *The role of future public research investment in the genetic improvement of UK grown crops*

57 *Ibid.*

58 Defra states that "private breeding programmes….cannot justify the exploitation of new technological advances on their own to support the breeding of crops for 'public good' purposes". See Defra website on arable crop genetic improvement and breeding http://defrafarmingandfoodscience.csl.gov.uk/0/assessment.cfm?programmeid=25&unitid=1&assessmentid=49

59 SEERAD (2005) *Strategic Research for SEERAD 2005-2010: environment, biology and agriculture.* SEERAD notes "it has become clear that there is a role for Government in public good breeding in order to address crops or traits not emphasised in commercial programmes".

60 BBSRC's crop science review also recently recommended that a public good plant breeding initiative should be established. BBSRC (2004) *Review of BBSRC-funded research relevant crop science: A report for BBSRC council.*

61 NIAB have recently put forward a proposal for a national centre for public good breeding with a focus on technology transfer. Information from NIAB, February 2005

62 For example, a collaborative approach between small firms seems to be beneficial in France and Germany and some have suggested this could be encouraged in the UK.

66. **There also seems to be potential for increased coordination and greater support in the UK for research for developing countries**.

67. The sale of PBI and the shift of research into the private sector have left a gap in support and training for plant breeding scientists in the public sector. Although this is part of a wider agricultural research problem, there is **a need to maintain the scientific expertise base in plant breeding in the UK.**

Incentivising industry to work to more sustainable agriculture objectives

68. With a high proportion of research in the private sector, market forces have an important influence on research agendas, resulting in breeding for traits primarily around increased yield and quality. This has benefits for farmers and consumers in terms of improved agricultural outputs, but unless targeted in the correct way, could lead to an under-emphasis on the environmental and social goals promoted by Government. For breeders to develop products more in line with sustainable agriculture objectives, a market-pull is required. Several breeders we have spoken to acknowledge that there are certain traits that they know could have environmental or social benefits, but cannot research themselves as there is a limited market for the products, and a great investment of cost and time would be required.

69. Therefore, in addition to public sector support for research and knowledge transfer, **Government needs to influence the market** in order to create demand for products that contribute towards sustainable agriculture objectives, and therefore encourage the industry to generate these products. This could be done through regulatory, fiscal or other means. In fact, this approach may be the most effective method to persuade industry to meet Government's social and environmental goals. **We endorse the recommendation of the report for Defra[63], which states "Defra should continue to seek to reform the economic signals from CAP, legislation, taxation etc to create the incentives for environmentally beneficial genetic improvement."**

70. One additional way to influence this would be through the Recommended Lists. Policy decisions in the 1980s ceased Government involvement in near-market research, and subsequently led to the withdrawal of involvement in the lists. There are now discussions about a potential 'green list' but it is uncertain how much influence this will have without significant refocus of the market. Traits such as improved disease resistance are often correlated with decreases in yield so farmers may chose higher yielding varieties and use chemical disease control. There is therefore potential to influence the agro-chemical market in a similar way to that described in the paragraph above. As noted in the section above, communication with farmers, breeders and other parts of the food chain will be key to ensuring this is effectively embedded.

71. Related to this is **ensuring the regulatory and legislative framework does not inappropriately hinder the industry** and is not anticompetitive, although detailed comment on this is beyond the realms of this study.

63 ADAS and Biohybrids Ltd (2002) *The role of future public research investment in the genetic improvement of UK grown crops*

72. **Effective communication about the new sustainability agenda** is also needed, explaining precisely what is required from breeders. Several people we have spoken to in the industry feel that it is unclear what is expected of them and lack confidence in a stable policy agenda. Given the long timeframes involved in breeding, it is also important that **communication is held at an early stage of policy development to enable breeders to 'catch up' with policy shifts.**

Addressing science in society issues

73. Technology has undoubtedly been an important driver in plant breeding, especially when the new biotechnologies were first developed and there was much activity in both the public and private sectors to capitalise on them. This excitement around technology however has been tempered by negative public reaction, to GM in particular.

74. This has been useful in the sense that it has spurred more research into wider questions such as environmental effects of various crops and encouraged research in a broader framework that is not solely focused on technology as an end in itself. However, the 'backlash' to technology could hamper progress in plant breeding, which would not be beneficial for economic, social or environmental goals. The BBSRC crop science review concluded that it was necessary to restore public confidence in plant breeding through focusing on public good objectives.[64] However, in order to do this, **it is important that the technology drive works alongside, and towards the aspirations of society. Improved engagement of the public and a diversity of stakeholders in the early stages of technology development would help move towards this**.

75. This exercise has provided us with an interesting insight into the way that various influences have shaped the research agenda in plant breeding. The four key drivers identified by the Commission in its general information gathering exercise[65] have all had an effect on plant breeding research, although we have encountered a range of differing views on whether these effects have been positive or negative. In developing our conclusions we have attempted to reflect the diversity of opinion and provide a balanced overview of the issues as we see them, whilst concentrating on practical suggestions for the future.

64 BBSRC (2004) *Review of BBSRC-funded research relevant crop science: A report for BBSRC council*
65 AEBC (2005) *What shapes the research agenda? Information and Analysis Paper* **URN: 05/1082**

Annex 1: List of those who have provided input to this study

All those listed below were sent a draft of this case study, to which they responded in writing, through a face-to-face meeting or by telephone.

Organisation	**Individual**
Advanta Seeds UK*	Thomas Joliffe
Biogemma Ltd.*	Tina Barsby
BBSRC	Sophie Laurie, Brian Harris
British Beet Research Organisation (BBRO)	John Macleod
British Society of Plant Breeders	Penny Maplestone
CPB Twyford*	Chris Tapsell
Defra (Science Directorate)	Donal Murphy-Bokern, Bruno Viegas,
DFID (Central Research Department)	Bob Carlisle, Jonathon Wadsworth
DFID (Plant Science Research Programme, Bangor)	John Witcombe, David Harris
FARM	John Turner
National Institute for Agricultural Botany (NIAB)	Brian Legg, James Reeves
Nickerson*	Bill Angus
Oxford University Plant Sciences Department	Chris Leaver
RAGT*	Richard Summers
University of Reading Soil Science Department	Peter Gregory
Scottish Crop Research Institute	Gavin Ramsay
Warwick HRI	Simon Bright

* Denotes member of the British Wheat Breeders

Annex 2: Table to show funding by the UK levy boards and related trust spending on the genetic improvement of UK-grown crops (£000 in FY2001-02).[66]

Crop	Levy board/ funder	Research, breeding, technology	Germplasm development	Variety trials and recommended lists	*Total*
Apples and Pears	APRC	11	-	2	13
Cereals	HGCA	172	119	979	1270
Oilseeds	HGCA	40	-	205	245
Hops	NHA	42	-	-	42
"	EMTHR	25	-	-	25
Horticultural crops	HDC	8	-	37	45
"	EMTHR	347	138	-	485
Pulses	PGRO	-	-	125	125
Potatoes	BPC	35	35	135	205
Sugar Beet	BBRO	165	89	293	547
	Sub totals	845	381	1777	3002

66 Table reproduced from Laurie S. (BBSRC) (2005) *The landscape of plant genomics in the UK*. Information gathered as part of the ERAnet in plant genomics.

Annex 3: Table of companies breeding crops for the UK[67]

Crop	Company; R&D UK	Other/related companies; R&D EU
Wheat	Advanta, RAGT, Nickersons (=Limagrain), CPB-Twyfords Ltd (=Lochow Petkus = KWS), Syngenta (New Farm Crops) – feed and distilling wheat. Elsoms – niche UK feed wheat Cebeco is also breeding in UK	Cebeco DLF (v. small EU programme/Germany and Denmark) Saaten-union – 6 german breeders Advanta(=Unisigma FR), RAGT, Limagrain, Lochow Petkus, Serasem (FR coop), Desprez (FR), Cebeco (NL) Saaten Union (DE larger breeders group), IGP (DE smaller breeders group), Sejet (DK), Svalof Weibull (SE)
Barley	Advanta, RAGT, Nickersons, CPB-Twyfords Ltd, Syngenta	Secobra (French maltsters) and most of the wheat list
Oats	Scalof-Weibull Seed UK (=Semundo)	Svalof Weibull (SE)
Maize	No R&D in UK. Advanta and KWS have UK trials progs. Several others have minor trialling here	Advanta Limagrain, KWS, Monsanto, Pioneer, Syngenta, PauEuralis, RAGT, Maisadour
Rape	Syngenta (=Dippe), Nickersons(=Limagrain), KWS=CPBT=Momont, RAGT, Monsanto, Saaten-Union (=Raps), Elsoms, CBP Twyfords/KWS.	With exception of Elsoms most of same list will appear in EU as in UK Danisco (DK) NPZ (DE)
Sugar Beet	Advanta, KWS, Syngenta, Lion seeds (tiny in Essex).	Same big 3
Pulses	Mainly field peas – Advanta vining peas and field peas. Unilever vining peas Small amount of field beans – Werrys (PBI)	DLF(DK)=Cebeco(NL) Pioneer, Desprez, Unisigma(=Advanta),Axel Toft (small DK), Danisco (DK field peas and vining) Saaten Union, Nickerson, Svalof Weibull (SE)
Forage grasses	DEFRA-IGER in association with Germinal Biggest UK breeder. DARD & Queens University – N.I. Horticultural and Plant Breeding Station in association with Barenbrug. CPB Twyfords, and Zelder minor UK progs Of the big 3 at least DLF & Advanta have fairly big UK trialling	Big 3: DLF (Danish – took over Cebeco recently), Advanta (Dutch based), Barenbrug (Dutch based), RAGT and Serasem in France Amalgamation Hunsballe (DK)/DSV (DE)/Zelder (NL = Eurograss
Potatoes	Cygnet potato breeders (Harleys seeds) SCRI	No information at present
Other vegetables	Vining peas – Unilever; integrated in the end user community with a genomics research programme at Colworth including a tomato fruit quality programme. Advanta, UK. Elsoms, brussel sprouts, purple sprouting broccoli, spring cabbage, swede, Tozers, Cool season vegetables (brassicas, lettuce, leeks, onion, parsnip, radish, courgette) Syngenta; tomato fruit quality. Nickerson Zwaan (Limagrain) Seminis	

67 Table reproduced from Laurie S. (BBSRC) (2005) *The landscape of plant genomics in the UK*. Information gathered as part of the ERAnet in plant genomics.

Annex 4: List of acronyms

AEBC	Agriculture and Environment Biotechnology Commission
AFRC	Agriculture and Food Research Council
APRC	Apple and Pear Research Council
BBRO	British Beet Research Organisation
BBSRC	Biotechnology and Biological Sciences Research Council
BPC	British Potato Council
BSPB	British Society of Plant Breeders
CGIAR	Consultative Group on International Agricultural Research
Defra	Department for Environment, Food and Rural Affairs
DFID	Department for International Development
DTI	Department of Trade and Industry
EMR	East Malling Research
EMTHR	East Malling Trust for Horticultural Research
GIN	Genetic Improvement Network
GM	Genetic Modification
GMO	Genetically Modified Organism
HGCA	Home Grown Cereals Authority
HRI	Horticulture Research International
IGER	Institute of Environmental and Grassland Research
JIC	John Innes Centre
MAFF	Ministry of Agriculture Fisheries and Food
NHA	National Hop Association
NIAB	National Institute of Agricultural Botany
NSDO	National Seed Development Organisation
PBI	Plant Breeding Institute
PBIC	Plant Breeding International Corporation
PBR	Plant Breeders Rights
PGRO	Processors and Growers Research Organisation
RAE	Research Assessment Exercise
SCRI	Scottish Crop Research Institute
SEERAD	Scottish Executive Environment and Rural Affairs Department

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