Institution: Aberystwyth and Bangor Universities - Biosciences, Environment and Agriculture Alliance (BEAA)

Unit of Assessment: 6: Agriculture, Veterinary and Food Science

Title of case study: The breeding of novel types of oat with improved grain composition has changed retail and consumers' habits to the benefit of the UK oat crop as a healthy human food and as a high value livestock feed.

1. Summary of the impact

Oats are recognised as a healthy grain reducing the risk of coronary heart disease and as a valuable grain for livestock feed. Research within BEAA has provided the genetic, physiological and agronomic knowledge that underpins the breeding of high yielding husked and naked oat varieties that meets the needs of end-users in the human food and livestock sectors. BEAA bred oat varieties account for approximately 65% of the UK market and have a significant impact on health and welfare, the economy and on production and support the expanding instant oat breakfast market sector that alone is worth £160million per annum.

2. Underpinning research

Research conducted within BEAA through BBSRC, DEFRA, AHDB-HGCA and Sustainable Arable LINK funded projects, over the period 1993-2013 has underpinned the breeding of new oat varieties for human food consumption, as a livestock feed and as a source of novel compounds for industrial applications. Research by Leggett (Aberystwyth,1972-2004) and Carver (Aberystwyth, 1975-2007) focused on the identification of key traits (dwarfing genes, disease resistance [3.1]) that would enhance the value of oats for end-users, the potential for exploiting wild relatives of hexaploid oats as a source of novel genetic variation and made significant advances in the development of the genetic tools and resources available to plant breeders that enable genetic information on key traits to be more readily applied within the oat breeding programme. In recognition of this approach the variety Gerald, first RL listed in 1993, won the NIAB Cereals Cup in 2003 and dominated the winter oat market for a number of years [3.2]. Recognition of the subsequent breeding activity is also evidenced by the addition of varieties to the UK recommend list for cereals [3.2] and of the scientific quality of this research by the award of several major research grants during the REF period [3.3].

The value of oats for both human and livestock consumption is related to the specific composition of the oat grain. Oats are regarded as a healthy human food due to the composition of the grain, specifically the β-glucan content. Analysis by Leggett of oil content and composition [3.4] and beta-glucan content [3.5] has underpinned the oat breeding programme for both sectors and quantified the variation in β-glucan content within and between cultivated oats and their wild relatives and so released the potential for exploitation of wild relatives as a source of novel genetic variation. More recent research by Howarth (Aberystwyth, 1985-present) [3.6] on DArT marker development has enabled the breeding of varieties with high levels of β-glucan.

Oats are regarded as a high value animal feed. Naked oats have a non-lignified husk that is removed during harvesting. Research by Ougham (Aberystwyth, 1983-2010) [3.7] was carried out on the contrasting reproductive development of naked and husked, specifically lignin deposition. Later research showed that the naked oat trait greatly increases the metabolisable energy (ME) for poultry, for which the husk is almost indigestible. Research by Cowan (Aberystwyth, 1989-present) [3.8] has since shown that oats are a high-energy grain suitable as a monogastric feedstuff with a well-balanced protein composition rich in essential amino acids. This makes naked oats ideal for inclusion in animal diets as an energy source and has underpinned the breeding of naked oat varieties and demonstrated their value as a high value feed for monogastrics.

3. References to the research

3.1 Prats, E, Carver, T.L.W., Lyngkjaer, M.F., Roberts, P.C. and Zeyen, R.J. (2006). Induced inaccessibility and accessibility in the oat powdery mildew system: insight gained from use of metabolic inhibitors and silica nutrition. Molecular Plant Pathology 7 (1), 47-59. DOI: 10.1111/J.1364-3703.2005.00315.X

3.2 Gerald UK Winter Oat. Recorded on HGCA Recommended Lists for 2012/2013 for cereals and oilseeds. Published by AHDB-HGCA, this provides details of the yield, quality and agronomic performance (resistance to diseases, pests and lodging) of recommended varieties of cereals (including oats) and oilseeds. Gerald was awarded the NIAB Variety Cup in 2003.

3.3 (i) QUOATS- Defra Sustainable Arable Link (£4.9million, 2009-2014). Lead applicant (includes funding from BBSRC and additional funding through the WAG A4B programme). "Harnessing new technologies for sustainable oat production and utilisation".
(ii) Technology Strategy Board - "Generation of oat varieties with enhanced resistance to crown rust and mildew" (£425k, 2010-2015)

3.4 Welch R.W and Leggett J.M. (1997) Nitrogen content, oil content and oil composition of oat cultivars (*A.sativa*) and wild *Avena* species in relation to nitrogen fertility, yield and partitioning of assimilates. J. Cereal Sci., 26,105-120 DOI 10.1006/jcrs.1996.0109

3.5 Welch, R.W., Brown, J.C.W. and Leggett, M. (2000). Interspecific and intraspecific variation in grain and groat characteristics of wild oat (Avena) species: very high groat (1-3), (1-4)-beta-D glucan in an Avena atlantica genotype. Journal of Cereal Science 31, 273-279. DOI: 10.1006/jcrs.2000.0301

3.6 Tinker, N.A., Killian, A., Wight, C.P., Heller-Uszynska, K. et al. (2009). New DArT markers for oat provide enhanced map coverage and global germplasm characterization. BMC genomics 10, paper 59. DOI: 10.1186/1471-2164-10-39

3.7 Ougham, H., Latipova, G. and Valentine, J. (1996). Morphological and biochemical characteristics of spikelet development in naked oats (Avena sativa L.). New Phytologist 134, 5-12. DOI: 10.1111/j.1469-8137.1996.tb01141.x

3.8 Macleod, M.G., Valentine, J., Cowan, A.A., Wade, A., McNeill, L. and Bernard, K. (2008). Naked oats: metabolisable energy yield from arrange of varieties in broilers, cockerels and turkeys. British Poultry Science 49 (3), 368-377. DOI: 10.1080/00071660802094164

4. Details of the impact

BEAA's research on oat genetics has made a significant contribution to the breeding of innovative oat varieties that have had considerable impact [5.1]. Oat breeding within BEAA also formed part of the award of the Queens Anniversary Prize for 2009 that was awarded to Aberystwyth University [5.2] in recognition of combining fundamental research on plant genetics with plant breeding techniques to develop new commercially viable plant varieties that are designed to tackle some of the pressing issues faced by communities across the world, those of food, water and energy security.

Impacts on health and welfare:
Public awareness of the merits of healthy food and the health benefits of consuming oats has increased over recent years. This coincides with the publication of the health claim on oats by the EU [5.3] that accepts that eating oats contributes to a reduced risk of coronary heart disease because of their β-glucan content. BEAA's research on variation in β-glucan content in oats has identified sources of high β-glucan that has been incorporated into the winter and spring oat breeding programmes, providing suitable varieties for the UK milling industry. The BEAA oat breeding programmes account for approximately 65% of the oats used within the UK [5.4] and

varieties from that programme contribute to market diversification in oat based products within the breakfast cereal market and for snacks or light meals for consumers. There is a growing demand in the UK for on-the-go convenient breakfast foods. As a result, consumers are increasingly opting for cereal bars, instant porridge and other breakfast solutions. The oat varieties bred by BEAA are marketed through a strategic alliance with the company Senova [5.5]. The utility of the new oat varieties in terms of milling quality is tested in collaboration with the British Oat and Barley Millers Association, which represents the major oat milling companies within the UK. In 2012, the quantity of oats used within the UK was ca.700,000t of which 65,000t was imported, with 450,000t milled for human food consumption [5.4].

Impacts on commerce:
BEAA oat varieties based on our research activities [section 2] account for approximately 65% of the oats used in the UK and have a significant impact on the agriculture sector. The instant market for oats in the UK as of May 2013 is worth more than £120 million, with "Oats So Simple" alone worth £97.3 million [5.6] and is now the 3rd most valuable cereal in the UK. Porridge sales are £40 million putting the UK market for hot oat cereals at over £160 million. The BEAA oat varieties also impact on other sectors: the ready to eat cereals, granolas and mueslis market is approximately worth £19 million and bars and biscuits nearly £10 million. Sales of oat-based products are increasing at 5% per annum. BEAA research thus contributes to the improved human diet as a consequence of the increasing popularity of oats in the retail market. Economic impact is not only in the UK as the UK is also a major exporter of oat products into Europe, the Middle East, Africa and Asia; 55% of the output of the QUAKER mill at Cupar is exported and almost all as packed retail products.

In the UK the majority of the oat crop comprises BEAA's winter oat varieties; spring oats represent ca. 25% of the crop. The Crop Evaluation Limited Recommended List (RL) of winter oats is currently dominated by BEAA varieties (eg 100% in 2012). The winter oat variety Mascani, bred by BEAA (RL listed in 2004), is currently the most widely grown, accounting for nearly 50% of the current winter oat seed sales [5.7] with 60,000ha of land sown for production of this variety. Two BEAA bred spring oat varieties (Glamis and Conway) are currently on the UK National List and are in RL trials. The oat crop is used for human food and also for animal feed; the BEAA breeding programme introduced the 'naked oat' types in which the husks thresh free from the groat during harvesting, and these are favoured as feed for pigs and poultry. The BEAA naked oat breeding programme has bred varieties with high oil content and high ME value making them a quality animal feedstuff. Three (of 9) RL varieties of winter oats and one spring oat (Lennon) listed in 2012 are naked oat varieties bred by BEAA [5.7], further emphasising the impact of the BEAA breeding programme on the diversification of the market for the oat crop. The merits of these naked oat varieties, marketed by Agrii [5.8] are listed in the UK RL guide 2012/2013 [5.7]. Approximately 8500t were produced in 2012 with 18.8% going to the poultry sector, 14.1% to pet food, 9.9% for bird food, 16.4% for pigs and 40.8% for horses and malting.

Impact on production:
The BEAA research on dwarfing genes in oats has enabled the development of dwarf varieties, such as Balado, added to the UK RL in 2010, that reduce the risk of lodging [5.9], and the need to apply plant growth regulators to control plant height. This is evidenced by the relative performance of dwarf oats in comparison with conventional height oats with and without plant growth regulator (PGR) treatment [5.9]. Balado is the highest yielding winter oat currently on this list [5.7]. The dwarf oats have a significant impact on the production of oats and on the milling industry where grain without PGR is increasingly important, particularly for the export market to Scandinavia [5.6]. Research on disease resistance has also enabled varieties with improved resistance (such as Mascani) to be bred, reducing the need for fungicide application. The UK Recommended List for Cereals [5.7] 2012/2013 provides details of the disease resistance of the different varieties

5. Sources to corroborate the impact

5.1 Economic Impact of the Institute of Biological, Environmental and Rural Sciences: Research and Operational Activities DTZ Report 2009.
http://www.aber.ac.uk/en/media/departmental/ibers/pdf/DTZ_report.pdf

5.2 Queen's Anniversary Prize for Higher and Further Education 2010 The Award acknowledges the work of scientists at the Institute of Biological, Environmental and Rural Sciences (IBERS) who have successfully combined fundamental research on plant genetics with plant breeding techniques to develop new commercially viable plant varieties that are designed to tackle some of the pressing issues faced by communities across the world, those of food, water and energy security.

5.3 http://www.efsa.europa.eu/en/efsajournal/doc/2207.pdf - The Scientific Opinion on the substantiation of health claims related to beta-glucans from oats and barley and maintenance of normal blood LDL-cholesterol concentrations (ID 1236, 1299), increase in satiety leading to a reduction in energy intake (ID 851, 852), reduction of post-prandial glycaemic responses (ID 821, 824), and “digestive function” (ID 850) pursuant to Article 13(1) of Regulation (EC) No 1924/20061. EFSA Panel on Dietetic Products, Nutrition and Allergies (NDA)2.

5.4 HGCA MI Prospects 20 February 2013, vol 15 (16) – this provides detailed market analysis of different crops within the UK.

5.5 Letter from Director of Senova Ltd – they market the oat varieties bred by IBERS within the UK.

5.6 Oat market value – The Grocer magazine 10 August 2013.

5.7 HGCA Recommended Lists for 2012/2013 for cereals and oilseeds. Published by AHDB-HGCA, this provides details of the yield, quality and agronomic performance (resistance to diseases, pests and lodging) of recommended varieties of cereals (including oats) and oilseeds.

5.8 Agrii Yearbook 2013- through GB seeds they market the naked oat varieties within the UK

5.9 NIAB/TAG Network- Seed Handbook for Agronomists 2012/2013- This seed handbook gives comprehensive coverage of all major arable and livestock crops utilised in the UK including the tables highlighting the relative merits of the most popular varieties of these crops