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

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

Title of case study: Industry investment in a *Miscanthus* breeding programme for UK and global sustainable energy, and the fair and equitable use of natural resources

1. Summary of the impact

BEAA has created a world leading collection of *Miscanthus* genetic resources. This collection and associated expertise has led to an impact on commerce through investments by industry in *Miscanthus* science and plant breeding. *Miscanthus* is a highly productive grass which naturally occurs in Asia and is of interest as an energy crop worldwide. A second impact has therefore also been achieved through the implementation of international policy on the fair and equitable use of natural resources. The experience and knowledge gained through this impact has provided an example for others to follow and is being used to support UK and EU legislation and policymaking.

2. Underpinning research

Our *Miscanthus* breeding program started in 2004 led in Aberystwyth by group leaders Dr John Valentine (retired July 2012) and Dr John Clifton-Brown and focussed on the suitability of the crop to northern Europe conditions [3.1, 3.2] with a focus on the use of energy crops as an important component of any future energy mix to help national governments meet greenhouse gas emission and renewable energy targets. A new breeding programme is dependent on the collection and characterisation of genetic resources. BEAA scientists have therefore assembled *Miscanthus* genetic resources including collections made in Asia from 2006-2012 [3.3]. Earlier collections were made by taxonomists and horticulturalists and did not have the accompanying international agreements in place for commercialisation. BEAA researchers have expanded on these collections and targeted germplasm which exhibits traits for agricultural production and industrial end uses. For the new collections from Asia, seed and rhizome have been imported, quarantined and the relevant necessary agreements put in place with donor countries.

Collected *Miscanthus* materials have been planted in trials in Aberystwyth and in collaboration with partners in academia and industry in the UK, continental Europe, North America, and Asia. Industrial partners include: Ceres Inc., E-On, Biocatalysts, Blankney Estates, NFU and Terravesta. Ceres signed a 15 year partnership agreement with BEAA in 2007 for the improvement and commercialisation of *Miscanthus* as an energy crop. The *Miscanthus* trials have generated information on the matching of genotype to different climates and also for different end uses from bioenergy through to chemicals and materials. Research in BEAA has focused on performance of diverse *Miscanthus* germplasm under UK conditions. This research has helped to define crossing strategies and ideotypes for *Miscanthus* and also through modelling which regions in Asia contain the most desirable traits [3.4, 3.5, 3.6]. In addition DNA based molecular markers have been developed with industry to identify parents for wide crosses and for use in selection programmes [3.7, 3.8].

In accordance with the guidelines of the United Nation's Convention on Biological Diversity (CBD), which has been ratified by 193 countries, each country is sovereign over its own genetic resources with the aim of governing the fair and equitable use of genetic resources. Any new genetic resources collected since 1992 needs to be CBD compliant. However, the implementation of CBD is still in its infancy and only a limited number of countries have implemented access and benefit sharing legislation. So far a multi-lateral mechanism for access and benefit sharing has been put in place for 64 main crop plants (so called Annex 1 species). Following the adoption of the 2010 CBD protocol on access and benefit sharing in Nagoya it became possible to enter into bi-lateral agreements with donor countries. As *Miscanthus* has not been used as a crop species to date, BEAA scientists John Clifton-Brown (project leader, 2004-present) and Lin Huang (researcher, 1999-present) have developed bi-lateral agreements with several donor countries for commercialisation of *Miscanthus*, one if not the first time this has been done for any non Annex 1 crop.

3. References to the research

3.1. **Valentine J** (PI). The genetic improvement of *Miscanthus* for biomass - NF0426. Defra Grant NF0446. 2004-2009. £1,216,288

3.2. **Clifton-Brown JC** (PI). Genetic improvement of *Miscanthus* as a sustainable feedstock for bioenergy in the (GIANT) – Defra/ BBSRC Renewable Materials LINK Grant LK0863. 2011-2016. £3,036,657 with additional industrial match income.

3.3. **Clifton-Brown JC** (PI). *Miscanthus* germplasm collection from the Far East. Defra Grant NF0436. 2006-2007. £25,001

3.4. **Jensen E, Robson P, Norris J, Cookson A, Farrar K, Donnison I, Clifton-Brown J.** (2013) Flowering induction in the bioenergy grass *Miscanthus sacchariflorus* is a quantitative short-day response, whilst delayed flowering under long days increases biomass accumulation. *Journal of Experimental Botany* 64: 541-552. Doi: 10.1093/jxb/ers346

3.5. **Robson PRH, Farrar K, Gay AP, Jensen EF, Clifton-Brown JC, Donnison IS** (2013) Variation in canopy duration in the perennial biofuel crop Miscanthus reveals complex associations with yield. *Journal of Experimental Botany* 64: 2373-83. Doi: 10.1093/jxb/ert104

3.6. **Farrar K, Donnison IS, Clifton-Brown JC, Robson PR, Jensen EF, Hawkins SL**, Kenobi K & White S (2013) Accelerating the domestication of a bioenergy crop: identifying and modelling morphological targets for sustainable yield increase in Miscanthus. *Journal of Experimental Botany* (in press). Doi:10.1093/jxb/ert225.

3.7. Ma X-F, **Jensen E**, Alexandrov N, Troukhan M, Zhang L, **Thomas-Jones S, Farrar K, Clifton-Brown J, Donnison I**, Swaller T, Flavell R (2012) High resolution genetic mapping by genome sequencing reveals genome duplication and tetraploid genetic structure of the diploid *Miscanthus sinensis*. *PLoS ONE* 7(3): e33821. Doi:10.1371/journal.pone.0033821.

3.8. **Slavov G, Robson P, Jensen E, Hodgson E, Farrar K, Allison G, Hawkins S, Thomas-Jones S**, Ma X-F, Alexandrov N, Troukhan M, Zhang L, **Huang L,** Swaller T, Flavell R, **Clifton-Brown J, Donnison I (** 2013) Contrasting geographic patterns of genetic variation for molecular markers vs phenotypic traits in the energy grass *Miscanthus sinensis*. *Global Change Biology Bioenergy* 5: 562-571. Doi: 10.1111/gcbb.12025

4. Details of the impact

The most promising plant species for biomass production are those which produce high outputs with low inputs in terms of nutrients, husbandry and water. *Miscanthus* is a tropical grass which exhibits the C4 photosynthetic pathway and a particularly advantageous set of physiological traits which make it one of the most promising energy crops worldwide.

Impact on commerce where industry has invested in research and development

To realise the potential of *Miscanthus* as an energy crop requires research and the development of new varieties. BEAA has collected one of the world's largest e*x-situ* collections of genetically diverse *Miscanthus* outside Asia and used this to build a crop improvement programme for UK and Europe. This has created significant interest in the programme from industry resulting in investment by Ceres Inc, a US based energy crop company). Since 2008 Ceres has invested >£1M in cash and has provided further in kind contributions to enable large scale field trials in the EU and USA. This includes new seed based varieties which were planted on farms in the UK in 2012 and 2013. This is a successful example of exploiting novel genetic resources through partnership with industry [5.1]. In addition since 2011 a Renewable Materials Link project, GIANT, has expanded industrial investment into *Miscanthus* research and development in BEAA to now also include E-On, Biocatalysts, Blankney Estates, NFU and Terravista. The total value of this project is approximately £6M with £3M coming from industry. This is a public-private partnership with public

funding from DEFRA and BBSRC which was announced alongside a speech by PM David Cameron in April 2012 to energy ministers from 23 leading economies [5.2]. For example to quote this announcement: *"Today also saw the announcement from Aberystwyth University Institute of Biological, Environmental and Rural Sciences that it has secured funding from the UK Government to work in collaboration with industry to develop an integrated Miscanthus breeding platform. This industry-led research project will generate new plant varieties which enable the production of new feedstocks for commercialization."* Since 2008, the total investment on *Miscanthus* at BEAA by private and public sectors has been >£17M. This has included funding by DEFRA [3.1, 3.2, 3.3], BBSRC (BB/E014933/2, BBS/E/W/10963A01, BB/L003953/1, BB/I025727/1, BB/G016216/1, BB/E024319/2), NERC (NE/H01067X/1), EPSRC (EP/E039995/1), Welsh Government, Energy Technologies Institute, EU Framework (OPTIMISC FP7-KBBE289159, OPTIMA FP7-KBBE289642, and WATBIO FP7-KBBE311929 projects) as well as the industrial partners mentioned above. In addition between 2009-2013 there have been five BBSRC CASE student projects with Ceres on *Miscanthus* (Grant references: BB/G017484/1, BB/H016481/1, BB/J012572/1, BB/K012258/1, BB/K012509/1).

Impact on public policy and service through implementation of international policy

Through our research and implementation of an international conservation policy, the United Nation's Convention of Biological Diversity (CBD), BEAA has achieved an impact toward the implementation of public policy at the global-scale for the conservation of genetic resources. The CBD entered into force on 29 December 1993 following the United Nations Conference on Environment and Development (the Rio "Earth Summit"). The Convention was inspired by the world community's growing commitment to sustainable development and represented a dramatic step toward the conservation of biological diversity, the sustainable use of its components, and the fair and equitable sharing of benefits arising from the use of genetic resources.

New crop breeding programmes are dependent on the collection and characterisation of diverse genetic resources. Importantly since the domestication of the staple crops, legally binding contracts including the CBD have been put in place to ensure that where genetic resources are collected from one country and commercially exploited elsewhere, the benefits of the exploitation are shared with the donor country.

BEAA researchers pioneered the making of new *Miscanthus* collections and the negotiation of the necessary agreements in the absence of clear national legislation for the implementation of the access and benefit sharing arrangements under the CBD and prior to the implementation of the Nagoya Protocol on Access and Benefit Sharing in 2011. BEAA scientists worked closely with DEFRA and partners in Asia to implement the CBD and access and benefit sharing protocols through organising joint workshops, collaborative research and legal negotiations. For example an International Workshop on Green Chemistry and Biomass Energy which was jointly funded by the National Science Council of Taiwan and the BBSRC, was held at the National Cheng Kung University on 3 November. Aberystwyth University and National Cheng Kung University formally signed a memorandum of understanding at the workshop, the signing of which was presided over by the vice chancellor of the Cheng Kung University and the CEO of BBSRC [5.3].

In May 2012, Taiwan was the first Asian country to sign a full access and benefit sharing agreement [5.4] under the CBD framework with the UK, and this was followed by successful negotiations with South Korea during January 2013 to July 2013 and an official signing in October 2013 [5.5, 5.6]. On both occasions the UK was represented by BEAA in the negotiation. This has created one of the first examples for implementing Nagoya protocols in the UK and our partnering countries. Not only have BEAA scientists implemented two international agreements but their experience and knowledge of setting up bi- lateral access and benefit sharing agreements under the CBD framework is now also being used as a proven example for others to follow, supporting the UK government's approach to proposed EU legislation in this area [5.7, 5.8]. This includes the UK government's approach to the proposed "Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization (Nagoya Protocol): Union implementation and ratification", an EU-wide legislation to be submitted to the European Parliament which was voted on in committee on 4 July 2013 [5.8, 5.9]. The main beneficiaries of this policy impact are therefore

the UK government's agriculture policy legislation body (DEFRA), donor countries in Asia, commerce (only compliant germplasm can be commercially exploited in signatory countries) and the global society on the conservation of natural resources.

5. Sources to corroborate the impact

5.1. Collaboration agreement between Ceres and IGER (now IBERS, Aberystwyth University): http://yahoo.brand.edgar-online.com/EFX_dll/EDGARpro.dll?FetchFilingHtmlSection1?SectionID=8025268-1055599-1288160&SessionID=jlOvFqxOZWVY8T7

5.2. Citations in press release by PM David Cameron on 26 April 2012: https://www.gov.uk/government/news/prime-minister-heralds-rapid-progress-of-the-uks-green-economy-and-outlines-his-vision-for-the-future

5.3. Reference to the international Workshop on Green Chemistry and Biomass Energy: http://www.sinoptic.ch/taiwan/science/2011/201112_ST_Taiwan.News.pdf

5.4. Signed access and benefit sharing (ABS)/ convention on biological diversity (CBD) agreement with Taiwan.

5.5. Minutes of GIANT LINK management meeting reporting work done to gain agreement on access and benefit sharing (ABS)/ convention on biological diversity (CBD) agreement with South Korea.

5.6. Signed access and benefit sharing (ABS)/ convention on biological diversity (CBD) agreement with South Korea.

5.7. Letter from Ceres Inc.

5.8. Letter from Defra UK national focal point for CBD and Nagoya Protocol on Access and benefit sharing of genetic resources.

5.9. European Parliament Procedure File 2012/0278(COD) Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization (Nagoya Protocol): Union implementation and ratification. http://www.europarl.europa.eu/oeil/popups/ficheprocedure.do?reference=2012/0278%28COD%29&l=en