Institution: Aberystwyth and Bangor Universities - Biosciences, Environment and Agriculture Alliance (BEAA)
Unit of Assessment: 6: Agriculture, Veterinary and Food Science
Title of case study: Maize variety GM-6 brings £55 million of benefits to more than 300,000 resource-poor farmers in Western India

1. Summary of the impact

GM-6, a new maize variety developed through innovative Bangor crop breeding research (pioneering the use of participatory plant breeding) was released in three states in Western India between 2002 and 2005. Since its release, GM-6 cultivation has rapidly grown to a cumulative area exceeding 2M hectares, of which 54% (more than 1M ha) was during 2008-2013, with a major positive impact on the welfare and prosperity of at least 330,000 households per year. Because of its advantage under drought and on poor soils, GM-6 has average grain yields 28% higher than the best available alternative varieties, providing 360,000 t of additional food grain during 2008-2013 with a total net present value to these farm households of an average of at least £9M per year.

2. Underpinning research

Professor John Witcombe (JRW), in BEAA's Centre for Advanced Research in International Agricultural Development (CARIAD) 1990-present, started research to develop new varieties of maize in 1994 through participatory plant breeding (PPB), which was specifically designed to meet the identified needs of resource-poor farmers in the more arid regions of Gujarat, India. It used his novel research-based participatory varietal selection (PVS) method (Witcombe et al. 1996). This approach to PPB incorporates on-farm varietal testing and farmers' experiences with, and reactions to, new varieties from the breeding program. This was the first published example (Witcombe et al. 2003) of the application of PPB in maize, and included several research innovations to increase the efficiency of mass selection in the crop. JRW made further innovations to introduce properties desired by farmers, such as (i) breeding for very early maturity and (ii) using both yellow- and white-endosperm maize as parent varieties to combine the superior yield of yellow maize with the preferred taste and colour of white maize.

This research produced new varieties highly adapted to the requirements and preferences of local farmers, which greatly improved their popularity and adoption rate. One of these varieties, GM-6, had particular strong advantages in terms of yield (18% more than the local control variety in research-station trials, and a 28% advantage in trials on farmers' fields). In addition, GM-6 was superior for agronomic traits, e.g. extreme early maturity in less than 80 days (Witcombe et al. 2003). Farmers also highlighted GM-6's superior grain quality and the tightly packed cobs that reduce insect attacks, as well as production of higher quality fodder, which is a main source of animal feed. The resulting extremely high popularity of GM-6 amongst farmers is reflected in the high adoption rate of GM-6: between 1998 and 2000, over half the farmers that were given the seed continued to grow it in the next year and all farmers growing GM-6 for a second year became continuing adopters, growing GM-6 on 30-100% of their land (Witcombe et al. 2003).

This research, led by JRW, resulted in the official release of GM-6 for the whole of the Gujarat agro-climatic zone in 2002 by the Gujarat State Seed Certification Agency (GSSCA, Witcombe et al. 2003). It was notified in 2003 by the central variety release committee of the Government of India with the reference number S.O.383 (E)12-3-2003 REG/2007/338. It was subsequently officially recommended for cultivation in the states of Rajasthan (2004) and Madhya Pradesh (2005). JRW led research into the pathway of rapid uptake of this variety by farmers in the three states which was reported to the DfID Research into Use programme (Witcombe et al. 2007).

The research was a collaboration between Bangor University, the DFID-funded *Krishak Bharati Cooperative Rainfed Indo-British Farming Project* (KRIBP) and Gujarat Agricultural University

(GAU). All of the breeding research was done by Bangor and KRIBP, and the on-station testing by GAU, which also put the new varieties through the formal testing system and jointly proposed them for release. PVS on the maize varieties was organised by KRIBP with supervision and analysis by JRW. The impact of the maize varieties on the livelihoods of local farmers was surveyed by the Gramin Vikas Trust (GVT), Gujarat.

3. References to the research

BEAA authors are in **bold**. Citation counts obtained through Google Scholar (October 2013).

Witcombe, J.R., Joshi, A., Joshi, K.D. & Sthapit, B.R. (1996). Farmer participatory crop improvement. 1. Varietal selection and breeding methods and their impact on biodiversity. *Experimental Agriculture* **32**: 445-460. DOI: 10.1017/S0014479700001526. Published in a peer-reviewed journal, 274 citations, submitted to RAE 2001

Joshi, A. & **Witcombe, J.R.** (1996). Farmer participatory crop improvement. 2. Participatory varietal selection, a case study in India. *Experimental Agriculture* **32**: 461-477. DOI: 10.1017/S0014479700001538. Published in a peer-reviewed journal, 163 citations

Sthapit, B.R., Joshi, K.D. & **Witcombe, J.R.** (1996). Farmer participatory crop improvement. 3. Participatory plant breeding, a case study for rice in Nepal. *Experimental Agriculture* **32**: 479-496. DOI: 10.1017/S001447970000154X. Published in a peer-reviewed journal, 151 citations

The above three papers on participatory methods of plant breeding were the first to be published that dealt with the entire process and have been widely cited. The first of the papers above is the most widely cited in the fields of PPB and PVS

Witcombe, J.R., Joshi, A. & Goyal, S.N. (2003). Participatory plant breeding in maize: A case study from Gujarat, India. *Euphytica* **130**: 413-422. DOI: 10.1023/A:1023036730919. Published in a peer-reviewed paper, 59 citations, submitted to RAE 2008

Virk, D.S., Chakraborty, M., Ghosh, J., Prasad, S.C. & **Witcombe, J.R.** (2005). Increasing the client orientation of maize breeding using farmer participation in eastern India. *Experimental Agriculture* **41**: 413-426. DOI: 10.1017/S001447970500270X. Published in a peer-reviewed journal, 17 citations

Research into the pathway by which the maize breeding research led to impact through rapid uptake by farmers of the new GM-6 maize variety is reported in the following reference

Witcombe, J.R., **Virk, D.S.** & 9 co-authors from Indian institutions (2007). Client-oriented breeding in maize - improved varieties GM-6 for western India and BVM 2 for eastern India. Research into Use project report, PSP Dosier 15. Available at: http://www.researchintouse.com/nrk/RIUinfo/PF/PSP15.htm

4. Details of the impact

The new maize variety GM-6, developed by Bangor research using the novel methods of PPB and PVS, was successfully released in Gujarat State in 2002 and, as shown below, has had a major impact on food production in Western India between 2008 and 2013. The relationship between the research output (GM-6) and the impact is causal and direct and is related to the production and economic benefits of growing GM-6 and the area upon which it is grown. Because of careful targeting of farmers' needs during the PPB and PVS, the high benefits gained from the new variety did not require additional input of resources by the farmers. PPB and PVS produced a variety that was earlier to mature than any of those produced by conventional maize breeding, combined this

trait with high yield, and took fewer years to do so than conventional breeding methods [5.1, Witcombe et al. 2007 (cited in section 3)].

Impact on production and international development: improved food yield, security and economy

The impact resulting from the uptake of GM-6 on livelihoods of a sample of farmers in three states in Western India that had previously been given seed was surveyed [5.1]. Farmers liked the new variety for its higher yield as well as other traits such as improved grain quality, earlier maturity (7 days earlier silking than local varieties) and better tolerance of major diseases and pests. Because of its early maturity, GM-6 escapes terminal drought, resulting in a much lower frequency of failed harvests. Combined, these properties of GM-6 give a major advantage to resource-poor farmers, allowing them to sell more grain, as well as increasing their household food self-sufficiency. Farmers reported considerable impacts on their livelihoods with seed sales in maize increasing by 51% and food self-sufficiency by more than one month. Large-scale uptake of GM-6 during the 2008-13 period is attributable to the evidence that during its period of rapid uptake over 70% of the farmers growing this new maize variety reported an overall increase of more than 10% in their total income [5.1].

A comprehensive survey of the seed production records of the 13 main responsible institutions in the states of Gujarat, Madhya Pradesh and Rajasthan in western India by Yadavendra (2013) [5.2] showed that the amount of GM-6 seed produced for sowing has increased rapidly from 2002 to 2013 with a notable acceleration during 2010-2013 (Figure 1 below). During the 2008-2013 period 1519 t of GM-6 seed for sowing was produced (over 250 t per year), which represents 54% of the cumulative total seed produced since the release of the variety in 2002. These documented values are conservative as data are unavailable for private-sector non-certified seed. This indicates the sustained and accelerating demand for this seed amongst farmers. During 2008-2013 GM-6 accounted for over 91% of the total recorded maize seed production in Gujarat State, and in each year during 2011-2013 it accounted for at least 98% of the total production (Figure 2 below, [5.2]).

Based on an average sowing rate of 20 kg seed/ha, the 1519 t of officially certified GM-6 seed produced since 2008 enabled 76,000 ha of maize to be planted. Importantly, Yadavendra (2013) [5.2] determined that the actual area of GM-6 planted is much greater than this, equating to an estimated cumulative area of 1.08M ha since 2008. This was based on an estimate that 4% of farmers' harvest of GM-6 is sown as seed in subsequent years. This estimate is conservative as previous surveys [5.1] found that farmers themselves sowed an average of 3% of the seed of GM-6 that they harvested and distributed an additional 6% to relatives, friends and neighbours for sowing. This estimated is further supported by the finding of Yadavendra and Witcombe (2013) [5.1] that more than 60% of farmers who were given GM-6 seed more than once grew it in the following year and increased the proportion of their land area sown to this variety year-on-year. Independent evidence for this large estimated land area planted with GM-6 is provided by the principal maize research scientist at the Main Maize Research Station, Gujarat Agricultural University, Godhra who concluded from his observations that GM-6 is the most popular maize variety in Gujarat, that it occupies a large majority of the maize area, and that it has been grown on a cumulative area of 2M ha since its release in 2002 [5.2].

Surveyed resource-poor farmers reported that cultivating GM-6 maize had considerable positive impacts on their livelihoods with their maize seed sales increasing by more than 50% and their household food supply lasting for more than one additional month [5.1]. In addition, a majority of the surveyed farmers growing GM-6 reported that it increased their total income by 10-20%. Given that, on average, resource-poor households in Gujarat each own 0.9-1 ha of land, which is only partially planted to maize, it is estimated that the cumulative 1.08 million ha of GM-6 planting during the six years 2008-2013 equates to the livelihoods of an average of more than 2 million household-years (333,000 households per year) directly benefitting from GM-6. Using conservative estimates for current value of maize grain and the estimated 30% yield advantage obtained from cultivating GM-6 over other local varieties, GM-6 has provided an additional harvest for farmers in Gujarat, Rajasthan and Madhya Pradesh States of 360,000 t of food grain during 2008-2013 with a

net present value of Rs 5,600M (£55M) [5.2, page 33], a major direct impact on international development of the Bangor-led research that created GM-6.

There are also good grounds for inferring substantial beneficial impacts on the environment as the increased productivity of GM-6 is achieved without the need for additional inputs, specifically water, inorganic N and pesticides, thus reducing the burdens of water-consumption and polluting agro-chemicals per amount of food production.

Figure 1.

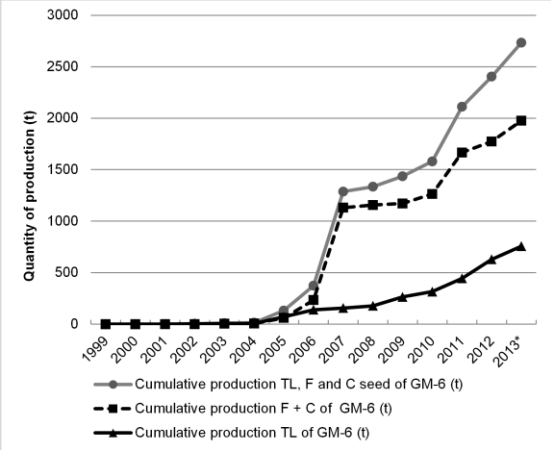

Figure 2.

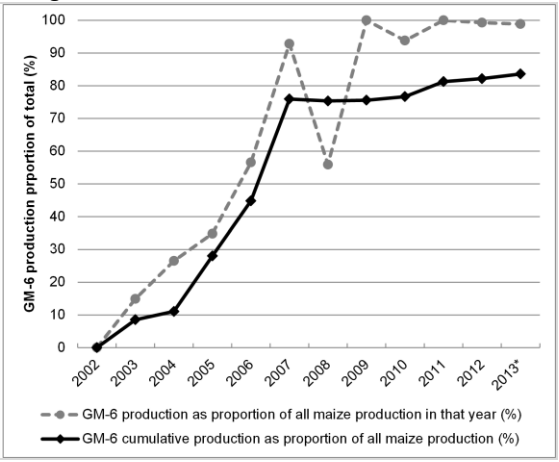

Figure 1. Cumulative production of GM-6 seed (t) for truthfully labelled seed (TL, black solid line), foundation (F) and certified (C) seed (black dotted line) and all three categories combined (grey line) over the period 2002-2013. 60% of all seed was distributed during 2008-2013 at an average rate of over 250 t per year.

Figure 2. GM-6 cumulative production as a proportion (%) of all cumulative maize seed production (black line) and as a proportion (%) of production in each separate year (grey line) in Gujarat State over the period 2002-2013. In all years from 2009 GM-6 accounted for > 90% of seed production.

** 2013 figures are extrapolated based on the average of the previous three years.*

5. Sources to corroborate the impact

5.1 Yadavendra, J.P. and Witcombe, J.R. (2013). The impact of maize and rice varieties from client oriented breeding on the livelihoods of poor farmers in western India. SABRAO Journal of Breeding and Genetics 45: 132-142.

5.2 Yadavendra, J.P. (2013). Spread of Gujarat Maize-6 (GM-6): A maize variety bred by participatory plant breeding released in Gujarat and recommended in Madhya Pradesh and Rajasthan in Western India. Available at: http://gvtindia.org/templates/theme1/upload_files/Spread_of_Gujarat_Maize-6_final_28_sept.pdf

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