



**PROGRAMME OF RESEARCH AND
TECHNOLOGY TRANSFER FUNDED BY THE
BRITISH BEET RESEARCH ORGANISATION
2009/10**

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FOREWORD

This compilation of project synopses provides brief outlines of the aims of all projects current in the BBRO research and technology transfer programme. Projects are grouped in six general categories. The compilation is intended to be a convenient *aide memoire* and will be updated annually.

Suggestions for improvement of the document would be welcomed by the Secretariat.

J. E. King
Programme Manager
April 2009

GROUP 1

GENETIC TECHNOLOGIES, CROP IMPROVEMENT, VARIETIES

06/20 Evaluating genes for controlling premature bolting and root rot diseases in sugar beet – Broom's Barn Research Centre

The main objective of this proposal is to enable breeders to develop more bolting resistant varieties. The benefits from this include early sowing possibilities, and reduced weed beet pressure. A second objective is to introduce control of root rot disease. These targets will increase flexibility in crop management, reduce production costs and improve containment of traits in future GM crops. The project will deliver tools (genes, promoters, molecular markers) and knowledge that will immediately assist breeders with selection of their own material and provide them with new data to enable informed choices between non-GM and GM breeding strategies in future bolting resistant varieties.

The project has two key aims. The first is to integrate a new BBSRC-funded “sugar beet flowering gene” project (and its associated collaboration to a sugar beet TILLING project), with BBRO-funded work. In essence, sugar beet genes identified in the BBSRC-funded project and found to be key candidates for controlling the onset of flowering in vernalised plants will be taken into the BBRO project, transformed into sugar beet and tested for their ability to confer bolting resistance. In a separate collaboration from BBRO, sugar beet flowering gene sequence data from the BBSRC-funded project will be used to develop probes for screening chemically mutagenised sugar beet, in an effort to identify mutations that may confer bolting resistance. This part of the project will be conducted in collaboration with Prof. Jung's group at the Plant Breeding Institute in Kiel, Germany and will involve the use of their new sugar beet TILLING technology platform; a powerful research tool that is available to us only through this collaboration. Already a number of TILLING mutants with significantly delayed bolting have been identified and will be the immediate source of genetic material to be screened for mutations in candidate genes from the BBSRC project. Identification of such mutations will give rise to strategies for engineering transformation cassettes that can be used for transgenic analysis (in *Arabidopsis thaliana*) of the TILLING associated mutations in isolation. Should this independent flowering gene/TILLING collaboration yield positive results – i.e. identify mutations in the sugar beet flowering genes that result in delayed flowering (as determined in the *A. thaliana* model), then the same gene constructs should be tested also in sugar beet as part of the proposed BBRO project. Random chemical mutagenesis, as applied in TILLING, provides an alternative to genetic engineering in case breeders are obliged to use non-GM strategies. Breeders will therefore have the option of going back to Prof. Jung's original TILLING plants and using them in conventional breeding programmes. However, the subsequent breeding required to incorporate traits in elite varieties is more complex compared to GM approaches but at least the breeders will be made aware that, if required, the tools necessary for GM strategies will be available as transgenes (from the flowering gene/TILLING collaboration) or transgenic plants (from the proposed BBRO project

The second aim of our project is to evaluate the utility of the *ENDOCHITINASE* gene from the bio-control agent *Trichoderma harzianum* in conferring resistance to root rot disease in transgenic sugar beet. Tests will be conducted using existing transgenic sugar beet lines, developed as part of an earlier BBRO project. If proved, this trait could be improved further in future, by using inducible sugar beet gene promoters such as the wound-inducible ones that we have developed here at Broom's Barn. This latter aspect is however beyond the scope of the proposed project.

This project benefits from close technical links with key breeders and scientists in Syngenta and KWS. It is also highly leveraged, attracting BBSRC core grant support (£100k/year) and with plans to submit further grant proposals to the EU (major collaborative project) and BBSRC for additional support (£150k/year).

06/23 Using multi-environment variety trial data to screen for drought tolerance – Broom's Barn Research Centre

Insufficient moisture during summer months limits UK sugar beet production more than any other single factor. Climate change models predict that summers will get hotter and drier, giving production areas with deep, water retentive soils a competitive advantage. To maintain productivity under these conditions, new, more drought-tolerant varieties are required. In addition, varieties that are less sensitive to the prevailing moisture supply should exhibit greater site-to-site and year-to-year yield stability, improving management decisions for growers and processors. Currently, breeders are not equipped to make these selections and there is no mechanism in place for judging the relative drought performance of varieties entered into official variety trials. In a previous BBRO-funded project, it was shown that by assigning a drought stress index (DSI) to each trial location, certain varieties showed significantly better yields when water was limiting, while others showed good performance in the absence of drought but performed poorly when conditions were dry. This type of information would be extremely useful to farmers, processors and seed companies if included as a standard characterisation of all variety trial entries every year. By evaluating data already gathered in variety trials, additional value is added to this investment. Previous work has provided a database of soil types for nearly every field used in the UK variety trials. Automatic rainfall gauges at each trial location would eliminate reliance on costly, slow or incomplete weather data sources. The outcome of the proposed work will be a drought tolerance rating for Recommended List varieties. Furthermore, seed companies will be encouraged to take up the procedures for evaluation of in-house variety trials, giving them an additional drought tolerance screening tool to increase the prospect of improved varieties being introduced. Seed companies are showing interest (KWS is already committed) in contributing to this project.

07/14 Physiology-based selection methods for improving sugar beet productivity under water-limited conditions – Broom's Barn Research Centre

Limited soil moisture is the single most important factor that prevents the UK sugar beet crop from realising its full potential productivity, costing the industry approximately £30M annually in lost revenue. Climate change models predict that the situation will worsen. Furthermore, consolidation of the major growing area in the East means that a

greater proportion of the crop could be grown on farms receiving less rainfall. The goals of this research are to enable breeders to develop varieties that can 1) maintain a greater proportion of their yield potential when water becomes limiting; 2) recover faster from drought as stress is relieved. A key element of this research is the development of screening tools and know-how to identify superior germplasm in breeding programmes. However, breeding companies have committed only half the support needed to make a research programme viable, and partnership with the BBRO is required. The proposed work focuses on areas that are most likely to result in practical selection criteria. Instrumental in this work is a core set of genotypes that show consistent contrasts for drought tolerance, yield potential, leaf morphology, water use efficiency (WUE) and wilting. Carbon isotope discrimination ratio has been used with success to breed wheat varieties with improved WUE; one objective is to implement this technique in sugar beet. Also, leaf morphological characters are related to drought tolerance and WUE, but further work is needed to refine protocols so that breeders can begin to cull inferior breeding lines on the basis of these traits. Drought susceptible varieties show a greater tendency to wilt, but wilty types are difficult to identify in large scale rainfed breeding trials. Identification of limiting plant processes that cause wilting will lead to the development of more specific selection criteria. The ability to recover quickly following a dry period may be an important trait of superior varieties, but there is little information on this response. Experiments are proposed to gauge the relative importance of recovery, and to identify genotypes that contrast in the rate of post-stress yield formation. New, more drought tolerant varieties will give UK growers the ability to compete with competitors who have deep, water retentive soils and wetter summers. Also, varieties that are less sensitive to the prevailing moisture supply should exhibit greater site-to-site and year-to-year yield stability, improving ability to plan production with greater accuracy. This has important economic benefits for both grower and processor.

08/01 Sugar Beet Variety Trials 2008-2012 – NIAB, British Sugar plc and Broom's Barn Research Centre

The research programme will provide data for the preparation and selection of a Recommended List (RL) of Sugar Beet Varieties. The research is designed to monitor the development and improvement of sugar beet varieties made by breeding companies. A comprehensive set of field trials designed to assess agronomic performance, disease resistance and bolting levels is proposed. Carried out in collaboration with British Sugar and Broom's Barn, they will provide information for all sectors of the sugar industry for efficient variety selection and utilisation. Yield trials will be located within commercial crops and receive inputs appropriate to their locations and soil type. Additional trials will be early sown to measure levels of bolters. Special plots will be grown by Broom's Barn to assess variety response to inoculated levels of powdery mildew and rust.

09/22 Varietal differences in crown size and greater recovery of crown material at harvest – British Sugar plc

The project has three components:

- (i) To update the varietal database for biological crown size to include a large number of new varieties on the current recommended lists.

There has been a downward trend in the crown size of recently-introduced varieties which introduces a greater risk of yield loss through overtopping. An updating of information on biological crown size is needed to allow the potential commercial risk to the industry to be assessed and to make growers aware of it.

- (ii) To examine whether flail-only approaches to harvesting can be adapted to profitably recover the entire sugar-beet crown without unacceptably high levels of green material.
- (iii) To assess the processability of such beet in the factory.

More efficient factory processes and new opportunities of using low-value molasses now make the processing of the crown material less of a problem and financially attractive. This, together with the compelling need for the UK sugar-beet industry to raise average yields to 70 t/ha in order to remain viable and competitive with the rest of Europe, provides a case for re-appraising UK harvesting practices to seek ways of delivering more of the previously-discarded crown material to the factory.

09/26 Early-sown bolting trials to characterise varietal bolting – British Sugar plc

Increasingly mild spring temperatures during the past decade have meant that BBRO early-sown bolting trials that relied on early-March sowings no longer provide sufficient or consistent intensities of vernalisation for the bolting behaviour of new varieties to be fully characterised. A revised protocol for British Sugar's early-sown bolting trials is therefore submitted with two much earlier sowing windows - one in the second or third week of February and a second in late February, with each trial having three replicates of 1000 plants instead of two. Information from these trials will be supplemented with bolting data from the eight main variety trials sown in early to mid March. Hopefully, the combined dataset will provide a sufficient range of vernalisation to characterise varietal bolting in terms of specific *vernalisation requirements* and *bolting sensitivities*. Definition of these two attributes for current varieties in conjunction with the new BBRO vernalisation-intensity bolting model should help growers better assess the bolting risk arising from their choice of variety and sowing windows in particular locations. It will also enable us to model how bolting is likely to progress in these crops and so provide prior warnings of the need and cost of removing bolters to prevent future problems with weed-beet.

GROUP 2

DIRECT ENVIRONMENTAL IMPROVEMENT

07/25 Strip Tillage, a new concept sugar beet production – The Arable Group, British Sugar plc

The objective of this proposed project is to evaluate the potential for strip tillage for sugar beet production in England and to develop guidelines for its potential adoption. Strip tillage has been defined by the Conservation Technology Information Centre (CTIC) as a no-till system where only one third of the soil and crop residue is disturbed by cultivation over the field area. The strips have the crop residue placed in the inter-row with the seed being drilled into the strips in spring or autumn. Strip tillage has a number of potential benefits over conventional tillage including improvements to soil physical properties and the enhancement of in-field biodiversity. There are also other potential advantages in terms of reducing costs, energy consumption, global warming potential, over-winter nitrate losses, the carbon footprint of sugar beet production, soil erosion and diffuse pollution.

Strips can be created at a range of depths and so the technique may be appropriate to slumping soils such as the sands where deeper tillage is required. In addition, its flexibility in depth of working means that reduced tillage may also be adopted on fields with a range of soil types. The approach may also mean that harvesting of sugar beet may be achieved with less soil damage. Should this be a valid assumption then it opens up the possibility of the adoption of non-inversion tillage throughout a rotation that includes sugar beet with the consequent advantages over time of increasing soil organic matter close to the soil surface.

There are specialist machines used elsewhere in the world for producing strips that are suitable for sugar beet production and one has shown considerable promise in a PhD project at The Arable Group (TAG) Morley Research Centre. A similar machine is being introduced in Europe by Simba-Horsch. However, comparable techniques have also been developed for establishing narrow row crops in the UK; such a machine could have the advantage of reducing the costs of this approach. The project will not only examine specialist strip tillage machines but also whether existing narrow row machines could be adapted for sugar beet, by widening the row widths by removing some of the soil engaging units; an example of such a machine would be the Claydon drill.

The proposed project will be carried out on two soil types (medium loam and a sand) over two cropping years using specialist strip tillage machines as well as examining the potential for using machines such as the Claydon drill. The machinery aspects will be managed by British Sugar (BS) staff and the agronomic assessments led by TAG staff with BS support.

GROUP 3

PHYSIOLOGY & RESPONSE TO INPUTS & ENVIRONMENT

09/03 Inputs/outputs – effects of increased input costs on crop profitability – Broom’s Barn Research Centre

During the last year, input costs and returns have changed greatly for arable farmers in the UK. Fertiliser prices have doubled, pesticides costs have increased at more than twice the rate of inflation and the price of diesel has risen around 50%. These increases, combined with the effect of the sugar regime changes on the returns from sugar beet, are causing growers to question the levels of inputs that they should use. In many cases the increased costs will not alter the inputs required for optimal economic return. The yield response of sugar beet to most agronomic inputs is seldom linear and therefore the effect of changes to input costs on profitability are not always easy to determine. In addition, there are limits to what farmers can afford and, in some cases, an alternative strategy for inputs may be required; if not now then possibly very soon if costs continue to rise.

The BBRO has information on responses of beet to nutrient inputs and on the effects of diseases, pests and weeds on sugar beet yield. However, there is no information to hand for growers to determine how close their current input costs are to the economic optima. In some cases, this may result in them cutting back on inputs unnecessarily such that they reduce their profitability.

The aim of this project is to help growers to maximise yields by providing them with useful models so that they can determine the cost-effectiveness of inputs, to give them confidence to use appropriate inputs and, also, to help the BBRO determine where ‘pinch points’ are likely to occur and where research or development is required.

GROUP 4

PEST, DISEASES & WEEDS

07/12 Monitoring and control of sugar beet pathogens – Broom's Barn Research Centre, British Sugar plc

This new integrated plant pathology project, condensed from three original Concept Notes as requested by the BBRO Board, has been developed in close consultation with the BBRO Scientific Advisory Committee. It aims to achieve durable control of the major sugar beet diseases in the UK by monitoring pathogen populations to predict breakdown of resistance and advise on the need for chemical control, and to develop novel sources of genetic resistance where this is currently unavailable, inadequate or vulnerable to erosion.

Virus yellows forecasts will be issued each year and aphid numbers monitored via the network of water pans in collaboration with British Sugar and other industry representatives; the infectivity of the individual sugar beet aphids will be determined. Annual surveys of the yellowing viruses will be undertaken to determine the distribution, significance and biological properties of BMV, BChV and BYV along with any new strains or viruses. The yield impact of these viruses on current and future varieties (standard and rhizomania resistant) will also be monitored in glasshouse and field studies.

The incidence, distribution and strain variation in the rhizomania virus, BNYVV will be monitored by testing samples from surveys or individual growers. Results will inform growers of the need to use resistant varieties and provide early detection of any resistance-breaking strains. Previously developed *Polymyxa* resistant lines will be tested for their ability to slow inoculum multiplication – of particular value in UK soils. Variation in the pathogen will also be examined to assess the likely durability of this form of resistance.

To date, no single major resistance genes to the yellowing viruses have been identified from *Beta* germplasm collections. Therefore, there are no prospects for conventionally bred resistance to the yellowing viruses. However, pathogen-derived resistance offers the potential to provide long term durable resistance to the yellowing viruses. It is proposed to continue to develop this concept, exploiting the findings of previous studies and using new approaches to develop plant immunity to BMV, BChV and BYV.

A glasshouse screening test for violet root rot will be developed and resistant sources selected, in order to kick-start breeding programmes for this disease, primarily to the benefit of UK growers.

08/16 Pest and Disease Decision Support System – British Sugar plc

Controlling pests and diseases is imperative if a profitable high yielding crop of sugar beet is to be grown. Pests and diseases can strike quickly and their effects can be very damaging and require immediate attention. There are many pests and diseases that can

affect sugar beet throughout the growing season. Some will require preventative measures while other pests and diseases are seasonal or occasional, and dependent on climatic or soil conditions. The magnitude of effect will vary, with yield being lost through plant loss or root or foliage damage. There is a wide range of control measures that can be used; some are cultural while others rely on insecticides and fungicides.

In order to prevent or control pests and diseases in sugar beet, it is vital that firstly they are correctly identified, and that secondly, all the relevant information regarding the control options is available to help growers and advisers take the right decision. Currently growers and advisers either use their current experience or need to search various documentation to find the most appropriate treatment. This can be more effectively achieved by the use of a web-based decision support system. With so many crop protection products available, such a system will narrow down the choices available, present all the currently approved pesticides, rank them in terms of cost and efficacy, and instantly give supplementary information to the grower/adviser.

Using both British Sugar and crop protection expertise, including Broom's Barn, technical information will be sourced and assembled for all pest and disease control options. A web-based decision support system will be developed in a similar way to the BBRO herbicide decision support tool using the expertise of external specialised web-designers. The system will feature online access to the most up-to-date pest and disease product approvals and label information. The Pest and Disease decision support tool will be made available for use by growers and advisers through UK Sugar Beet Portal and BS Online. It will become a useful, practical aid in the identification of pests and diseases and will assist growers and advisers to choose the most efficient and cost effective control options.

09/01 Optimising virus yellows control by monitoring population dynamics, virus content and insecticide resistance of aphids – Rothamsted Research

The objective is to optimise and sustain the use of insecticides against aphid pests of beet through monitoring and forecasting aphid dynamics, monitoring the insecticide resistance status of aphids, evaluating virus yellows risk, and transferring relevant information to the industry.

Regional forecasts of the timing and abundance of vector aphids, based on aphid data from the national suction trap network and on meteorological data from the BBSRC ARCMET network, will be updated annually and used to warn the industry of the likely level of virus yellows in crops grown from both neonicotinoid-treated and untreated seed.

Aphids will be monitored using suction traps throughout the growing season and the status of the following three resistance mechanisms in individual *Myzus persicae* in relevant traps will be determined:

- Enhanced esterase production (S+R₁, R₂, R₃), based on measurements of total esterase activity;
- Insensitive acetylcholinesterase (MACE), based on a PCR-based assay;

- Knockdown resistance (kdr and super-kdr), based on a PCR allelic discrimination assay.

The presence of beet mild yellowing virus in aphids will also be tested in order to alert us to any change in the usual low level of occurrence (1-2% of tested aphids).

All results will feed directly and immediately through to growers via the BBRO/Broom's Barn advisory Fax bulletins and complement results from the more localised monitoring programme of Broom's Barn project 07/12 – 'Monitoring and control of sugar beet pathogens', which uses yellow water traps.

The project will complement and feed into (as 'in-kind' contributions) a new SA-Link project due to commence in 2009 for three years. This aims to monitor several aphid species, including *M. persicae*, collected directly from field and glasshouse crops, for signs of resistance to neonicotinoids and also any changes in the frequency of MACE and kdr.

09/09 Exploitation of fungicides for foliar disease control – Broom's Barn Research Centre, British Sugar plc

Powdery mildew continues to be the major foliar disease of UK sugar beet, requiring fungicidal control every year in East Anglia. The majority (over 75%) of varieties sown in 2008 tend to have poor resistance to this disease. Triazoles or triazole mixtures now predominate in the fungicide market and offer varying levels of disease control along with physiological benefits, as demonstrated in the recent BBRO project 04/01 (Optimizing yield benefits from triazole and strobilurin fungicides). New active ingredients (e.g. trifloxystrobin, azoxystrobin, tetraconazole) continue to be introduced whilst some existing products (e.g. Punch C) may well be withdrawn in the near future. There is, therefore, a continuing need to test the available fungicides for their efficacy (against both mildew and rust), their yield boosting properties, the optimum sequences and their relative cost-effectiveness under different scenarios in order to provide growers with sound unbiased advice. This is especially important as most of the readily available remaining products will be more expensive than the cheaper but efficient options that have been available for some time.

The NIAB/BBRO sponsored variety trials show that some varieties exhibit a strong resistance to powdery mildew and may require new fungicide strategies. Growers need advice on the fungicide programmes required by these compared to the very susceptible varieties.

It is intended that the above programme will be underpinned by BBRO funding and strengthened by company sponsorship from both fungicide manufacturers and sugar beet breeders.

GROUP 5

HARVEST, HANDLING & STORAGE

08/08 Gap – analysis of discrepancies between yield potential and delivered yield – British Sugar plc and Broom’s Barn Research Centre

In England, sugar beet must compete with wheat and oilseed-rape for a place in the arable rotation. At today’s prices for wheat (c. £130/t) and beet (£20/t) the competition is stiff: the costs per tonne of beet must decrease. There is little if any opportunity to reduce input costs, so yield must increase rapidly. There is a target to increase commercial beet yields to an average of 70t/ha. Where should the R & D effort be concentrated to achieve this yield increase? Large differences exist between yields measured in experiments or simulated in mathematical models and those delivered to factories. This difference was 30% when it was last examined in detail in the 1980s (Jaggard *et al.*, 1984) and much of it was ascribed to headland management and losses during harvesting. Despite improvements in harvesting (Brown, 2006) and headland management strategies, the differences between simulated or experiment yields and delivered yields remain close to 30% (Jaggard *et al.*, 2007). The aim of this project is for Broom’s Barn and British Sugar to quantify, in selected commercial fields and contracts, the factors causing (a) the discrepancies between the potential yields (assessed from a model and from local experiments) and yields in the fields and (b) the discrepancies between yields in fields and delivered yields and how these relate to harvesting, storage and delivery practices. The findings will be conveyed to participating growers and will be used to inform the Technology Transfer Programme of those aspects of crop production where the greatest and fastest improvements in delivered yield might be made.

GROUP 6

TECHNOLOGY TRANSFER

06/15 A fully co-ordinated programme of information and technology transfer for the UK sugar beet industry – British Sugar plc and Broom's Barn Research Centre

The objective of the British Beet Research Organisation (BBRO) is to commission and implement research and technology transfer designed to promote a profitable, sustainable and environmentally sound beet sugar industry in which the competitiveness and profitability of UK growers and the processor may increase. The overall aim of this programme is to provide an effective technology transfer service.

Co-ordinated by British Sugar plc and Broom's Barn Research Centre, and guided by an industry survey of growers' technical needs, the technology transfer programme includes technical meetings alongside decision-maker training, field demonstration days, attendance at Cereals and other major agricultural events, operator training courses, technical bulletins in a variety of hard and electronic formats. Individual advice is given to growers by British Sugar's team of area managers.

These approaches are supported and evaluated by British Sugar's crop profitability and agronomy models that enable growers and the industry to monitor individual and overall performance in terms of yield, growing costs and profitability.

This programme, which is a collaboration between British Sugar plc and Broom's Barn Research Centre, further develops and improves the BBRO-sponsored industry education programme to help UK sugar beet growers meet the challenges of the new sugar regime and increased world competition from 2006 onwards. Political decisions mean the industry has to be prepared for lower prices. With declining beet prices, growers will need to reduce unit production costs to remain viable. Raising yields will be necessary in order to achieve this.

Day-to-day TT activity is co-ordinated by Colin Walters, British Sugar plc, and Mike May, Broom's Barn Research Centre, and implemented in collaboration with British Sugar's area manager Regional Co-ordinators Group. All activity is reported to the BBRO Board via a steering committee.

The value and effectiveness of this project is measured ultimately by the rate of increase of national sugar yield and by crop profitability. Other measures may be applied to cover things such as meeting attendances, adoption of best practices, etc.