**British Beet Research Organisation**

***FINAL REPORT***

**Inputs / outputs - effects of increased input costs on crop profitability – 09/03**

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**Executive Summary**

* Sugar beet growers face a constant uncertainty in their expected net crop returns because prices of input materials and beet can fluctuate widely as a result of market forces. Maximising yield is one of the major aims of sugar beet growers and so care is required before compromises are made regarding inputs to the crop. At present, growers can have great difficulty in assessing the cost-effectiveness of a given input in the sugar beet cropping cycle.
* The cost-effectiveness of any input depends on its cost (of purchase and application), and the price of beet balanced against the rate of yield increase or the prevention of yield decline from the use of that input.
* This project examined the economic returns from a range of inputs at different costs for both the input and the beet. The inputs investigated included nitrogen dose, weed control programmes, fungicide treatment against foliar diseases, control of virus yellows and plant population. The project also considered sowing and harvest dates.
* Within the project several response curves and their associated look-up tables were prepared. These can be used easily to determine the cost-effectiveness of a single input or a range of inputs on a cascading (multiple inputs) basis.
* The tables and graphs are included in this report. A prototype web page (using nitrogen inputs as an example) that could be used on the BBRO beet portal has also been prepared (a link to this is provided) to show how costs of inputs are taken into account.
* Future efforts should concentrate on establishing a user-friendly web-based yield calculator based on a full crop simulator. This yield calculator could be used not only to determine the cost-effectiveness of any inputs but also as a useful tool for growers to monitor their crop performance during the growing season, determine where improvements might be made and plan their harvests accordingly.

**Introduction**

For sugar beet growers, beet crop returns are invariably at the mercy of constant changes in the price of input materials such as seeds, fertilisers, fungicides, pesticides, herbicides and fuels. Economic returns also depend on beet price, levels of yield and the rate of increase in yield when a given amount of inputs is applied. Current ‘recipes’ or ‘blue prints’ are more or less designed for maximal beet yields. However, optimal crop returns must take into account changes in input costs relative to the crop value, which in turn is determined by the expected yield and beet price.

Even though there are defined relationships between sugar beet yield and most agronomic inputs, the effect of changes to input costs on profitability can be difficult to determine. The optimal input for best economic returns depends on prices of the input materials and the beet, as has been shown for mineral nitrogen fertiliser by Jaggard *et al*. (2009).

The first parameter that we had to calculate was the attainable yield, which is the highest level of yield that can be achieved given the prevailing conditions defined by the variety, soil characteristics, sowing and harvest dates and the weather between these two dates. A second parameter that is important to know is the harvestable yield, which is closest to the actual delivered yield to the factory. This is the attainable yield that is limited by sub-optimal conditions such as inadequate nutrient supply or poor plant populations (Qi *et al*., 2005a). Poor management of headlands, harvest losses, storage losses, diseases, weeds and pests also reduce yields compared with the attainable yields. Such yield limiting factors often can be modified by growers through cultural practices to narrow the gap between harvested and attainable yields.

Sugar beet yields are also subject to effects of genotype (i.e. variety) and environment as well as management and the interactions between them (G x E x M). It is important that when decisions for inputs are made, various levels of yield and their principal determining factors are known.

Our final model needed to allow interactions between inputs to be taken into account rather than treat each individually, because when inputs are reduced (or not applied at all) to save costs, yield can become lower than models might predict, or even appear negative in some models. Therefore our yield response to a given input was determined using relative yield values, which were calculated as a percentage of the highest yield that could be achieved with an individual input. This allowed us to provide response curves that could be applied irrespective of other inputs, thus preventing occurrence of ridiculously small (or even negative) yields which can happen with some models when yield reduction is calculated under multiple problem situations. Our models do allow calculations to be applied to a range of inputs in appropriate succession.

At present, it is difficult for growers to obtain information from a single place to assess the value of a given input in relation to its yield-associated net returns. In this project, we produced look-up tables and yield response curves that can help growers to determine the cost-effectiveness of some important inputs, giving them confidence to use appropriate amounts.

[Note: the values used in these curves are based on current accepted knowledge. If these change in the future (e.g. there is new BBRO funded work to check the optimum N rates and plant populations for high-yielding crops) then the appropriate models can be recalculated accordingly.]

**Objectives**

1. Prepare generic model for attainable (relative) yield based on the current Broom’s Barn model used for yield predictions.
2. Prepare look-up tables for input costs and output values
3. Prepare response models for fertilisers, pests, diseases, viruses and weeds.
4. Design and prepare an appropriate interface for this work for inclusion on the UKsugarbeet portal.
5. Test the models

**Project outcomes**

***Yield response to sowing date and harvesting date***

The first step for growers to assess the cost-effectiveness of a given input is to know the attainable yield of their crop. The best way to determine this attainable yield is to run a crop simulator like the Broom’s Barn sugar beet growth model (Qi *et al*., 2005b) that uses sowing and harvesting dates, soil type and appropriate weather data. This data can be either provided by the system or entered by users themselves.

An alternative way for growers to determine the attainable yield of their crop is to use historic records and look up the highest yield for the past few years, providing that the relevant field had an adequate beet population and had been maintained more or less free of weeds, diseases and pests, and was well fertilised. This can then be cross-referenced to the relative yield response curves for sowing date (Fig. 1 and Table 1) and harvesting date (Fig. 2 and Table 2) to determine the appropriate yield for the given sowing and harvesting dates of the crop concerned.

***Yield response to fertiliser nitrogen***

Fertiliser nitrogen (N) management is particularly important in sugar beet production. Low levels of N limit beet yields whereas too high levels reduce sugar concentration and sugar yield. As pointed out by Jaggard *et al*. (2009), apart from peaty soils, all mineral soils need external inputs of N for profitable yields. The relative yield response curve to N application rate and the associated table (Fig. 3 and Table 3) can be used to determine the cost-effectiveness of the N input.

***Yield response to population density***

Recent crop survey and experiments show that sugar beet yield is significantly affected by plant population density with the optimum within the range of 80,000 to 100,000 plants/ha (Jaggard and Burks, 2009). The best crop net returns depend on plant establishment rate, but the seed-rate range of 1-1.25 units/ha that captures 97% or more of the maximum crop net returns has not been affected greatly within the 70-90% of seedling establishment rates, which are normal for the UK crop. The relative yield response curve to population density and the associated table (Fig. 4 and Table 4) can be used to determine the cost-effectiveness of the seed usage per hectare. For example, if the seedling establishment percentage is known to be 75%, 1.13 units of seed need to be used in order to achieve about 85,000 plants/ha.

***Yield response to virus yellows incidence***

Recent observations show that the incidence of virus yellows has been low since 1996. However, it has been shown (Qi *et al*., 2005c) that in 12 of the last 14 years the crop in eastern England would have experienced severe virus yellows epidemics if neonicotinoid seed treatments had not been widely used. According to Stevens *et al.* (2004), a single infected plant would suffer a root yield reduction of 25%. Based on this assumption that 100% of plants infected with virus yellows would cause a total 25% yield reduction, the relative yield response to the virus yellows incidence is prepared and shown in Fig. 5 and Table 5. These can be utilised to determine the cost-effectiveness of controlling virus yellows diseases.

***Yield response to fungicide use in controlling powdery mildew***

Powdery mildew and rust are the two main foliar diseases likely to infect sugar beet in the UK. According to Asher and Williams (1996), a single sulphur spray for control of powdery mildew on average increased yield by 8%. However, recent work by Dr Mark Stevens at Broom’s Barn showed that powdery mildew can reduce yield by as much as 20%. Modern fungicides have replaced sulphur to control foliage diseases in sugar beet in the UK. These fungicides not only have the efficacy of sulphur in controlling powdery mildew but also have a role in enhancing yields through positive physiological effects (Asher and Ober, 2005). These physiological effects have been shown to increase yields by an average of 5%. So, the actual yield increase according to the latest experimental work should be 15% through control of powdery mildew.

Therefore, we assumed that modern fungicide treatments will increase yields by a total of 20%. For foliar disease-free conditions, the yield increase will be 5% if these modern fungicides are applied. An additional benefit from spaying foliage fungicides is that they help maintain a healthy canopy that can help protect beet from frost damage when beets are left in the ground over winter. Based on these findings, the relative yield changes as a result of controlling powdery mildew is prepared and shown in Fig. 5 and Table 5. They can be referred to determine the cost-effectiveness of controlling powdery mildew.

***Yield response to delay in control of weeds***

The recent trend has been that spring temperatures are becoming warmer and beet drilling is getting earlier as a result. However, for the past ten years under the UK maritime climate it has still taken 11-13 weeks for mid-March sown crops to reach over 80% crop canopy cover (i.e. by mid to late June). During this time, there is ample opportunity for weeds to germinate and establish. These weeds can compete with beet plants for water, nutrients and sunshine and reduce yields. The effects of weeds on yield depend not only on the stage when the weeds are controlled but also on the amount of weeds present (May *et al*., 2005). To determine the cost-effectiveness of herbicides, it is desirable that weeds should be classed into at least two groups – those taller and those shorter than the beet plants. However, we have assumed that the mixture of weeds for sugar beet fields were the same as that in the study by Scott *et al*. (1979).

It is important to define the window in which weeds should be controlled. Control should start in time to ensure they do not cause significant yield losses but stop once the crop is unlikely to suffer any subsequent significant loss from late emerging weeds. The study by Scott *et al*. (1979) showed that the starting and stopping period more or less coincided, at about 5 (4 to 6) true leaves. On average, once beet have 5 true leaves, yield was reduced by 1.5% for each day weed control was delayed. Depending on drilling date, it normally takes 4-6 weeks after emergence for beet plants to produce 5 leaves. Based on this knowledge, the response of relative yield to the delay in controlling weeds after the beet have 5 true leaves is given in Fig. 7 and Table 7. These can be used to determine the cost-effectiveness of controlling weeds.

**How can these response tables used?**

Since these relative yield response curves and tables for a given input can be applied independent of other inputs or, as they can also be applied irrespective of the yield levels the crop is set to be at the time, they can be used either on an individual basis or on a sequence of yield-reducing events, providing the order of cascading factors on yield is known.

***On an individual basis***

Using fertiliser N application as an example, if the attainable yield (worked out either using the crop growth model or with the historic yield records) was 68 t/ha, failure to apply fertiliser N would result in a yield at about 50 t/ha on mineral soils (see Fig. 3 and Table 3), a reduction of about 18 t/ha. If 100 kg N/ha was applied, the yield would be approximately 65 t/ha, a reduction of about 3 t/ha. However, if the attainable yield was 90 t/ha, zero use of fertiliser N would result in a yield of approximately 66 t/ha, a reduction of about 24 t/ha. If 100 kg N/ha was applied, the yield would be about 86 t/ha, a reduction of about 4 t/ha. Whether or not a particular amount of fertiliser N is profitable will depend on the price of the nitrogen, the beet price and also the rate of yield increase or reduction.

***On a cascading basis***

As a working example, we assume yield in a particular case is limited and restricted by population density, fertiliser N, weeds and powdery mildew foliage disease in this sequence.

If a grower knows that his plant establishment is around 70% and he uses one unit of seeds per hectare, this would produce a plant population of about 70,000 plants/ha. If the attainable yield is calculated to be 80 t/ha, this plant population would result in a yield of about 77 t/ha, a reduction of about 3 t/ha (see Fig. 4 and Table 4).

If the grower applies 100 kg N/ha, the yield would be approximately 74 t/ha, after a 4.1% reduction from 77 t/ha instead of from the attainable yield (80t/ha). The yield reduction from the use of 100 kg N/ha is about 3 t/ha (see Fig. 3 and Table 3).

If this grower also delays the weed control by about 5 days, the yield would be approximately 68 t/ha (after a 7.5% reduction from 74 t/ha instead of from the original attainable yield of 80 t/ha) and the reduction is rounded to 6 t/ha (see Fig. 7 and Table 7).

If there is powdery mildew infection that year and the grower decides not to apply fungicides with additional physiological benefits, the final yield would be about 54 t/ha after a 20% reduction from 68 t/ha (instead of from the attainable yield 80t/ha) and the yield reduction is thus about 14 t/ha (see Fig. 6 and Table 6).

The real loss from all of these cascading factors is approximately 26 t/ha but, if each had been assessed individually, the sum of the losses would have appeared to have been more, at approximately 28 t/ha.

**Future directions and lessons learned**

The outcomes of this work are for inclusion in the UKsugarbeet portal website so that sugar beet growers or advisors have easy access to it. For these response curves and tables to be effectively utilised, it is essential that a yield calculator based on a crop simulator like the Broom’s Barn growth model is available and, therefore, web-enabled. This yield calculator could then also be used for many other purposes, for example growers can use it to plan their harvests before the start of the campaign. However, as it has been pointed out in BBRO project 06/05 (‘Benchmarking grower’s production to the potential yield set by the environment’), issues still remain between British Sugar and the programmers at SilverBear Ltd before the web-based Broom’s Barn growth model can be migrated to the UKsugarbeet portal website.

In recent years, we have learned lessons when a project’s objectives included development of decision support tools which should be placed on the UKsugarbeet portal website. These are:-

* The cost for staff working days was inadequate when migration onto the portal took place.
* The host of work permissions required to enact the migration make the process expensive, inefficient and unproductive.
* More dedicated user involvement in the migration is needed to improve the utility and relevance of the process.
* Research on potential values of these decision support tools is required in order to determine the level of support required in the future.

A concept version of the potential website tool for inclusion in the portal is available at [http://www.rothamsted.bbsrc.ac.uk/broom/inputoutput/](https://webmail.bb.bbsrc.ac.uk/owa/redir.aspx?C=73ce4e9d329a4443bd87fc64ae229938&URL=http%3a%2f%2fwww.rothamsted.bbsrc.ac.uk%2fbroom%2finputoutput%2f).

This shows how costs of materials and price of beet can be included in the system.

This has used the N calculator as an example of how the tool might work. If you experience difficulties in accessing this website, contact Ian Pettitt (ian.pettitt@bbsrc.ac.uk) or Aiming Qi (aiming.qi@bbsrc.ac.uk).

**Conclusions**

Prices of both input materials and beet are subject to variable market forces making it difficult for growers to determine the economics of some of their inputs. Crop managers aim for maximum profit and, therefore, need to know the financial implications of their decisions on materials and manpower. It is important that growers are able not only to determine the cost-effectiveness of any inputs but they also need to know which aspects affect yields most. We have prepared relative yield response curves and tables related to management elements of sowing date, harvesting date, seed rate, N fertiliser, virus yellows, fungicide use and timing of weed control. Effective use of these curves and tables depends very much on the integration of a web-based crop yield calculator, based on a crop simulator, into the UKsugarbeet portal website.

**Staff who have contributed to this project**

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**Appendix**



**Figure 1** The response of relative yield to sowing date on sandy loam and clay loam soils.

**Table 1** The response of relative yield to sowing date on sandy loam and clay loam soils.





**Figure 2** The response of relative yield to harvesting date on sandy loam and clay loam soils.

**Table 2** The response of relative yield to harvesting date on sandy loam and clay loam soils.





**Figure 3** The response of relative yield to the amount of inorganic nitrogen (N) applied per hectare.

**Table 3** The response of relative yield to the amount of inorganic nitrogen (N) applied per hectare and its corresponding yield losses in percentage.





**Figure 4** The response of relative yield to plant population

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**Table 4** The response of relative yield to plant population and its corresponding yield losses in percentage.





**Figure** **5** The response of relative yield loss to the percentage of plants infected with virus yellows.

**Table 5** The response of relative yield to the percentage of plants infected with virus yellows and its corresponding yield losses in percentage.





**Figure** **6** The response of relative yield to presence/absence of powdery mildew (PM) and the use of fungicides with physiological benefits to control PM

**Table 6** The response of relative yield to presence/absence of powdery mildew (PM) and the use of fungicides with physiological benefits to control PM together with its corresponding yield losses in percentage.





**Figure** **7** The response of relative yield to the delay in days in controlling weeds after the beet plants have reached the 5 true leaves stage.

**Table 7** The response of relative yield to the delay in days in controlling weeds after the beet plants have reached the 5 true leaves stage and its corresponding yield losses in percentage.

