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Economic consequences for UK farmers of growing GM herbicide tolerant sugar beet

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Summary

Weed control is important and one of the more expensive inputs to sugar beet production. The introduction of genetically modified herbicide tolerant (GMHT) sugar beet would result in a major saving in weed control costs in the crop for growers, including control of problem weeds such as perennial weeds and weed beet. However, there would be other economic consequences of growing GMHT beet, some of which would manifest themselves in other parts of the rotation, such as the previous crop, the cereal stubbles that proceed most beet crops, soil tillage and spray application. The average national saving for UK sugar beet growers if they could use the technology would be in excess of £150 ha^{-1} yr^{-1} or £23 million yr^{-1}, which includes reductions in agrochemical use of *c.* £80 ha^{-1} yr^{-1} or £12 million yr^{-1}. However, for some growers, the gains would be much larger and for a few, less than these figures. The possible cost savings are sufficiently large that they could ensure that sugar beet production, with its regionally important environmental benefits as a spring crop, remains economically viable in the UK post reform of the EU sugar regime.

Key words: Sugar beet, herbicide tolerance, economics

Introduction

World sucrose production is around 133 million t per annum with the majority produced from cane and 28% from sugar beet (Anon., 2000). Sugar beet is grown mainly in Europe and North America. The current declared area in the UK is 150 000 ha and annual production is 1.4 million t of sugar (Anon., 2001). In this country, sugar beet is grown within arable rotations dominated by winter cereals and over 90% of that beet is preceded by cereals (Jaggard *et al.*, 1995). Approximately 34% of beet is grown on sandy loam soils, 24% on silty loams, 17% on sands, 16% on clays and 9% on organic soils. The annual cost of growing sugar beet in the UK is between £1000 (Leeds, 2002) and £1100 ha^{-1} (Nix, 2002). Variable costs account for over 30% of these and herbicides are one of the costlier inputs (Leeds, 2002). Average sugar yield in the UK between 1995 and 1997 was 8.6 t sugar ha^{-1} or 54 t roots ha^{-1} (May, 2001).

Adoption of GM herbicide tolerant (GMHT) sugar beet (Mannerlöf *et al*., 1997) would have greatest effect on weed control and expenditure on herbicides in the crop, but other benefits and costs also accrue. The various differences in input costs and outputs are considered in this paper and the financial consequences detailed in Table 1.

Calculation of Costs

For the purposes of this paper, it is assumed that GMHT sugar beet would be adopted by all farmers (Coyette *et al*., 2002), should the technique become available. Costs of inputs and changes in scenarios use data from published sources where these are available, but the author recognises that such figures can vary, as do those between seasons and individual farms. Where costs of herbicides are given without reference, the figure used is that paid by farmers in the vicinity of Broom's Barn, Suffolk, in 2001/2. The Annual Crop Surveys conducted by British Sugar are used as the source for some information. Current A & B prices for sugar beet (May, 2001) are taken as £28 adjusted t^{-1} and it is assumed that growers are producing 10% C beet. Therefore a price of £25 t^{-1} is used in relevant calculations.

A summary of the financial consequences is presented in Table 1. For all inputs and costings, calculations start with the cost per hectare where the input is used (column 1, Table 1). Where the topic is only relevant to part of the sugar beet area, the average national cost is calculated as the appropriate fraction (relevant area ÷ total national area) of the actual (column 1) cost ha^{-1}. In the final column of Table 1 the maximum gains or savings for an activity are presented. It is accepted that farmers would benefit from only some of the potential savings listed (e.g. farms on heavier soils

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are not susceptible to serious wind erosion, and those farmers with very low weed control costs, owing to sparse weed flora, may not save on control within the beet crop). Thus no attempt is made to total column 5.

GM varieties are not permitted in current organic rotations and, therefore, such cropping is not included in the comparisons in this paper.

Conventional Weed Control in the Sugar Beet Crop

Weed control is important because sugar beet is very sensitive to competition from weeds that emerge before the six-eight leaves stage of the crop (Scott *et al*., 1979). Early emerging annual weeds can reduce yields by 26%-100% (Schweizer & Dexter, 1987) if left uncontrolled. Weeds can also reduce harvester efficiency and increase storage losses. When seed treatments are excluded, herbicides account for 64% of the total pesticide treated area (Garthwaite & Thomas, 1999).

Current selective herbicides will only control weeds that are small (cotyledon to early true leaves stage) and therefore weed control starts either pre-emergence or early post-emergence of the crop (May, 2001). A sequence of four in the crop (Garthwaite & Thomas, 1999) or four to five sprays including preceding stubble treatments are typical (May, 2001), although on organic soils, where repeated weed flushes occur and growers adopt a repeated low dose approach, a sequence of seven applications is not unusual. Over 22 herbicide active ingredients and 300 herbicide products are registered for use in the UK beet crop (Anon., 2002*a*). Weed control in sugar beet is further complicated by the need to apply most herbicides as tank mixes in order to control a wide range of weeds. Mechanical weed control is probably used on *c*. 30% of fields but accurate information is hard to obtain. Surveys by British Sugar in the 1980s suggested that at that time the figure was greater than 66% of the area; however, since then it has been reduced and is mainly targeted at weed beet and difficult to control weeds. The cost of tractor hoeing is £30 ha^{-1} (Nix, 2002).

Current weed control practices in conventional

Table 1. *Cost comparisons*

	Current average cost £ ha^{-1} (where applicable	Average GMHT cost £ ha^{-1} (where applicable)	% area applicable	Estimated average savings or gains[a] £ ha^{-1}	Maximum saving or gain on individual field or farm £ ha^{-1}
Herbicide cost in beet	100-120	13-27	100	80	237
Herbicide applications	29 4.5 applications	13 2 applications	100	16	33 (e.g. peat soils)
Technology fee	-	20-30	100	-25	-30
Consultancy	3	0	100	3	10
Nozzle changes	1	0	100	1	1
One less sprayer					85
Weed beet and bolter control	15-500	5	70	10	500+
Yield loss from weed beet	6	0	7	2	138
Set-aside groundkeeper control	11	37	25	-8	-26
Rotational weed control	13	8	30	2	8
Stubble spraying	15	0	30	5	16
Manganese use	2	0	55	1	2
Insecticide use	11	0	10	1	11
Subsoiling	30	0	30	10	30
Minimum tillage	34	17	25	4	17
Wind erosion	22	0	5	1	19
Wind erosion – cost of redrilling					181
Wind erosion – loss of yield					73
Stewardship option					40
Reduced area owing to higher yield	0	50 reduction owing to less area required for contract[b]	100	50	
Total saving ha^{-1}				154	

[a]Mean of the national crop
[b]Excludes opportunity cost for alternative uses of the area

beet have three main costs – herbicides, application and, usually where weed beet is present, mechanical hoeing. The average annual herbicide cost ranges from *c.* £100 to £120 ha^{-1} (Leeds, 2002; Nix, 2002) depending upon season, although costs are variable and can range from £29 to £264 ha^{-1} on individual farms (Leeds, 2002) according to weed species present.

GMHT Weed Control in the Sugar Beet Crop

The current draft label for glyphosate tolerant sugar beet provides for a maximum of 6.0 litre ha^{-1} of the herbicide applied in two or three applications. The cost of the glyphosate formulation used (Roundup Biactive®) is £4.43 litre^{-1} and therefore maximum herbicide costs would be £27 ha^{-1}. Dewar *et al*. (2002) suggest that the average dose could be lower than this at approximately 3-4 litre ha^{-1} (suggesting a maximum saving of £106 ha^{-1}). There will be a technology fee (increased cost of GM variety) to add to the herbicide cost and this is likely to be in the region of £20 to £30 ha^{-1} (C Merritt, personal communication).

The average cost of herbicide application is £6.50 ha^{-1} for low volume (*c.* 100 litre ha^{-1}) applications (Nix, 2002). Hence a reduction of two spray passes per season would save an additional £13 ha^{-1}. However, Dewar *et al*. (2002) suggest that only one or two sprays will be required and that timing of these can be later and more flexible than with current herbicides, resulting in a saving of a further pass on some farms (i.e. a total of £19 ha^{-1}) whilst a saving of £33 ha^{-1} is possible on organic soil types if the current seven passes are replaced by two. The weed control from a two spray programme of glyphosate is likely to be as good or better than conventional programmes (e.g. Dewar *et al.*, 2003).

Sulfonylurea herbicides are used in many crops, including beet, and most of these require careful washout of the sprayer before the machine is used to treat susceptible crops (Anon., 2002*b*). The full procedures can take up to half a day to carry out correctly (at a cost of £18 for 3 hours labour (Nix, 2002)) and consequently, because beet is treated repeatedly, many growers have second sprayers specifically for that crop. A reduction in the number of spray operations and the flexible timing of glyphosate on GMHT beet would obviate the need for that second sprayer. The nominal annual cost for a separate sprayer (mounted 1200 litre, 24 m boom machine) is approximately £1100 annum^{-1} (Nix, 2002) (e.g. £18 ha^{-1} of beet on a farm growing 60 ha of sugar beet). However, if full depreciation costs were also included, the annual cost would be £4000 annum^{-1} (£20,000 cost of sprayer written off over 5 years) or £85 ha^{-1}. Many farmers grow a smaller area of beet than this (the UK average is 20 ha per grower), with a concomitantly higher cost of such a spare sprayer.

Most current beet herbicides are applied in low volume and as fine quality sprays (Southcombe *et al*., 1997) in order to get good coverage of the small weeds treated. Such applications pose a risk of spray drift unless conditions are calm. Therefore, many applications are applied in the early morning before the wind rises. Glyphosate applied to GMHT beet would be recommended as a medium quality spray and, therefore, is less prone to drift. The overall effect of the change would be to reduce pressure on spray operations and decrease the amount of work that is required at unsocial hours, at prime time rates and under sub-optimal weather conditions. It requires approximately 27 man h ha^{-1} to grow a beet crop (Nix, 2002) and the greatest use is at harvest, therefore the savings in man hours from the use of GMHT beet are unlikely to alter greatly the labour force on the farm. However, there would be a potential saving in overtime payments.

Fine quality nozzles are primarily used in beet and not in other crops on sugar beet holdings. Therefore, savings in nozzle replacement (£1.40 per nozzle) and fine filters (£2.50 each) on a 24 m boom (48 nozzles) every other year would be *c.* £1 ha^{-1}. The resultant extra applications of glyphosate would have negligible effect on the replacement cycle of medium quality, medium volume nozzles, especially when glyphosate applications in beet replace treatments elsewhere in the rotation.

Because spraying of GMHT beet could be delayed to await suitable soil conditions, this would reduce the risk of damage to soil structure from spray operations. In some seasons this would remove the need to subsoil after the beet to correct soil structure where the sprayer had passed repeatedly. The average cost for a farmer to subsoil is around £30 ha^{-1} (Nix, 2002). *Pro rata* to remove only tramlines and turning areas from 30% of the field area (more than 15% of field areas are headlands – Sparkes *et al*., 1996), the likely saving would be *c.* £20 ha^{-1}. For the purposes of calculating the national average benefit it is assumed that the saving would be achievable on approximately 30% of the area. However, severe damage to soil structure will result from harvesting when soil conditions are wet.

The selection and use of treatments from the 300 products approved for use as herbicides in sugar beet requires skill and management time. The flexible timing of glyphosate treatment in beet, and the fact that only one product would be required (i.e. no multiple tank mixes), would lessen the need for input from advisers who currently provide much advice regarding application timing and treatment selection. The average cost of independent advice for weed control in sugar beet is in the region of £10 ha^{-1}. Such advice is used on approximately 30% of the

sugar beet area and so the national average saving is of the order of £3 ha^{-1}. The majority of the advice to farmers (*c.* 60%) is provided as part of a package by herbicide suppliers; this saving has been included in herbicide costs.

Control of Weed Beet

One of the major weed problems in sugar beet is *Beta vulgaris* (weed beet). In 2001, British Sugar recorded it as present in 70% of UK sugar beet fields. Costs of control of weed beet vary between £15 to £500 ha^{-1} depending upon density and methods used to control the problem and can be in excess of £1000 for severe populations (May, 2000*a*). Hand pulling is recommended for control of low densities of weed beet, weed wiping for moderate populations and cutting for high infestations (May, 2001). Glyphosate used in GMHT beet would control weed beet for no extra cost, as it gives excellent control of non-tolerant *Beta* species without need for additional treatment or operation. Nationally there would be a probable saving where lower populations occur of approximately £15+ ha^{-1}. Unfortunately, there are likely to be some beet that 'bolt' (produce a flowering stem in the crop) and this ranges from 0% to 0.5% in current varieties (Anon., 2002*c*). This is likely to continue to occur in the future owing to contamination in seed growing areas (Desplanque *et al.*, 2002). Under a GMHT scenario, control of bolters would be essential to prevent the problem re-occurring with GMHT weed beet. The cost of this control would likely be in the region of £5 ha^{-1} for a simple walk through the crop to remove only the few bolters that occurred (weed beet would not be present). Therefore the national saving in weed beet control costs would be in the region of £10 ha^{-1}. However, for those farmers who are forced (generally owing to lack of alternative land on which to grow beet) to control dense populations of weed beet the savings would be much higher and could be in excess of £500 ha^{-1}.

A major benefit of using GMHT for weed beet control would be the opportunity to greatly improve control of this weed. Currently, many badly infested fields are only partially treated or even remain untreated and growers suffer a consequential yield loss (Longden, 1989). Longden (1989) showed that just one weed beet m^{-2} reduced yield by 11%. If it is assumed that 2% of the national crop is badly infested (= 1 m^{-2}) and 5% moderately infested with weed beet (0.5 m^{-2} = 5% loss), then the national yield loss for average 50 t ha^{-1} crops is around £6 ha^{-1}.

Under the current management systems, severely infested fields are too expensive to control and have to be taken out of sugar beet production. In such situations, the adoption of GMHT sugar beet would allow those fields to return to growing the crop. This would allow rotations to be extended with the consequential improvements to whole farm integrated crop management.

Beet groundkeepers (regrowth from roots or crowns left at harvest) in the following crops (usually cereals) or set-aside need to be controlled. There is unlikely to be an additional cost in cereals where sulfonylurea or hormone herbicides (e.g. MCPA) are used. In set-aside it is likely that a sulfonylurea herbicide (e.g. 30 g metsulfuron-methyl at a cost of £26) would be required to control GMHT bolters in addition to a cheap formulation of glyphosate (4 litre product ha^{-1} at £2.76 litre^{-1}) that is current practice in many fields. This would increase costs by around £26 ha^{-1}. As less than 25% of sugar beet is followed by set-aside, the increased cost nationally would be around £8 ha^{-1}.

Stubbles

Approximately 44% of the UK sugar beet area is sprayed with glyphosate between cereal harvest and emergence of beet (May, 2001). The treatment is primarily for rotational weed control and for control of volunteer cereals. Therefore, this could be replaced by the use of glyphosate in GMHT beet, because the weeds surviving primary cultivations (such as ploughing) or subsequent seedbed cultivation would be controlled in the beet crop. Average doses of glyphosate used on stubbles are in the region of 3.0 litre ha^{-1} resulting in a saving of approximately £8 (the cost of a cheap formulations of the herbicide) plus £7.50 application costs for a medium volume spray (Nix, 2002). If 30% of the stubbles were not sprayed prior to beet, this would result in a national saving of £5 ha^{-1}.

On light soils where ploughing can take place just before or at the time of drilling, this would facilitate uptake of Stewardship grants (currently £40 ha^{-1}) available to growers who leave cereal stubbles unsprayed and uncultivated until mid-February.

Rotational Weed Control and Benefits

The improved weed control in sugar beet could result in savings elsewhere in the rotation. The likely reduction in the cost of *Cirsium arvense* (creeping thistle) control in cereals would be in the region of £5 ha^{-1} (resulting from a change from metsulfuron-methyl at £13 ha^{-1} to cheaper herbicide at £8 ha^{-1}). Taking as an example a farm with 20 ha of beet, 280 ha other crops and 10% of field areas have *C. arvense* present (distribution of this weed in fields is normally patchy), this would result in an annual saving of £480 or £8 ha^{-1}.

An important advantage would come from using the GMHT beet to reduce inputs in other parts of the rotation without risk of increasing cost of weed

control in sugar beet. Results of Zimdahl (1995) and the Talisman project (Young *et al.*, 2001) suggest that some of the benefits of integrated weed control in cereals can be lost as a consequence of an increase in the weed seedbank in the soil. This increase results in more weeds emerging in 'open' crops such as sugar beet causing weed control costs in those crops to increase. However, in GMHT beet, these weeds could be controlled without significant additional cost, allowing more farmers to practice true integrated crop management throughout their rotation. The first record of glyphosate resistance occurred in *Lolium rigidum* (rigid ryegrass) following repeated treatments over a 15 year period (Powles *et al.*, 1998). Sugar beet is grown in rotation with other crops, primarily cereals, and so the use of glyphosate would be much more restricted and the development of glyphosate resistant weeds or shifts in the weed spectrum would be unlikely, unless all crops in the rotation were glyphosate tolerant and treated repeatedly every year.

The use of glyphosate in GMHT beet would provide an opportunity to control other pernicious or difficult weeds, such as herbicide resistant *Alopecurus myosuroides* (black-grass) (Moss *et al.*, 1999). Dewar *et al*. (2000) suggested that improved control of *Solanum tuberosum* (volunteer potatoes) by use of glyphosate in GMHT sugar beet could not only reduce the cost of control in sugar beet (currently *c*. £60 ha^{-1}) but could also reduce nematicide use in subsequent potato crops. This saving of nematicide is difficult to quantify and is not included in Table 1.

Tillage

Ploughing is the norm in most beet rotations, but it is more expensive than minimal tillage or direct drilling and it reduces earthworm and invertebrate populations. Perennial and grass weeds usually increase in non-inversion systems and thus weed control costs increase (Cannell *et al.*, 1978). However, the ability to control perennial and grass weeds in GMHT beet with minimal or no extra cost could increase the number of growers willing to adopt a minimum tillage approach in at least part of the rotation. For example, if two cereal crops in the rotation were sown with minimum tillage rather than ploughing, this would result in a saving of *c.* £17 ha^{-1} (ploughing costs on medium soils are around £34 ha^{-1} whilst minimum tillage is less than half of this). If this approach were adopted on 25% of soils, the national savings would be in the region of £4 ha^{-1}. Minimum tillage might be feasible on 40% of soils (Cannell *et al.*, 1978) but, for the purposes of this paper, it is assumed that there may be problems in obtaining good crop establishment on all of this area. In the future, direct-drilling might be developed, providing further savings.

Yield

Current herbicides are estimated to cause between 5% (May, 2000*b*) and 15% (Wilson *et al.*, 2002) yield reductions compared to a glyphosate GMHT system, mainly as a result of phytotoxicity of applications made when the crop is under stress. The lower, 5%, reduction is likely to be the norm in the UK. Under hot or more stressful seasons, the reduction will be nearer that recorded by Wilson *et al*. (2002). Growers using GMHT could, therefore, benefit from more consistent yields and might be able to reduce the area they grow to meet their contract with the processor. This would represent a saving of £50 ha^{-1} (5% of £1000). The reduction in beet area also provides the opportunity to sow an alternative crop on the area saved, or to use the area for environmental benefit (e.g. set-aside (Sparkes *et al*., 1998)).

This study assumes that GMHT varieties produce equivalent yields to current commercial ones. The GMHT sugar beet variety used in the DEFRA's Farm Scale Evaluation (Firbank *et al*., 1999) was developed some time ago and is considered to be outclassed. However, if GMHT were introduced, the glyphosate tolerant trait would be included in up-to-date varieties so that differences in varietal yield potential would to be very small or non-existent.

Minor Inputs

Many of the herbicides currently used in beet will damage the crop if applied at too high doses or when the crop is under stress (e.g. from frost, high temperature, nutrient stress), and direct yield effects have already been quantified above. However, the tolerance of glyphosate by GMHT beet is such that applications at times of crop stress do not reduce crop vigour or yield (Brants & Harms, 1998; May, 2000*b*) and further cost savings are possible in minor inputs. Conventional sugar beet often suffers from transitory manganese deficiency and growers mix manganese sulphate with herbicide sprays to reduce or avoid crop damage. Work at Morley Research Centre (May & Hilton, 1989) showed that, apart from reducing the impact of herbicides on yield, there was no yield or other benefit from the manganese applications, in the absence of herbicide treatment. The average cost of this manganese treatment is between £2-£3 ha^{-1}. Manganese is applied to 79% of the UK crop, but only the peat soils tend to be deficient. Therefore the area treated with manganese could be reduced by 70%, resulting in an average national saving of *c.* £2 ha^{-1}.

Similarly, where leaf burrowing pests, such as leaf

miner, damage beet, this can render the crop susceptible to herbicide damage with conventional herbicides. Therefore, growers tend to spray with insecticide to prevent yield reductions from following herbicide treatments. Cost savings of around £10.50 ha^{-1} (£3 ha^{-1} for the insecticide plus £7.50 for medium volume application (Nix, 2002)) or £1 ha^{-1} nationally (i.e. on 10% of the area) would therefore be possible if GMHT beet were used. The savings would be greater except that over 70% of the sugar beet crop is treated with imidacloprid seed treatment (Dewar & Stevens, 2002) that will control such pests.

Wind Erosion

Where soils are at high risk of wind erosion, growers will sow barley as a cover crop. A post-emergence foliar applied graminicide is used to control the barley when the crop is large enough to survive any wind blow. In a GMHT crop, glyphosate would control the barley for no extra herbicide cost, saving £20 on 5% of the crop area. In GMHT systems weeds could replace the use of barley because weed control can be left until the crop has six or eight leaves (Scott *et al*., 1979; Dewar *et al.*, 2003). This could save an additional £15 ha^{-1} (£5 seed, £10 sowing cost). It would also increase the area protected and, in cases where re-drilling is prevented, would save around £181 ha^{-1} (re-preparing the seedbed and re-drilling costs £42 ha^{-1} (Nix, 2002) and the seed plus imidacloprid, which is likely to be necessary for a late re-drilling, a further £139 ha^{-1} (Leeds, 2002)). There is always a yield loss from the re-drilling owing to the consequential delay in crop establishment. Yield losses in mid May are 0.6% day^{-1} (Hull & Webb, 1970) so that even a 10-day delay at that time would reduce income by £73 ha^{-1}.

Discussion

Whilst there have been discussions as to whether the price of GM sugar beet would be lower than that for conventional beet, the author has taken the view that as sucrose produced from GM or conventional crops is identical, such a differentiation is unlikely to be sustainable for sugar. However, EU farm ministers have recently proposed that all foods and feeds containing GM, even processed food products in which traces of GM cannot be detected, should be labelled. If public acceptance of the technology was gained and GMHT beet allowed, the adoption of the system would be widespread.

In this paper the economic aspects of changing to glyphosate treatment in beet have been discussed. However, adoption of this GMHT would also result in less active ingredient of herbicide being used (Coyette *et al.,* 2002). Glyphosate has a good environmental profile and adoption of GMHT would reduce further the impact of weed control in beet on water, and water and soil fauna (Wevers, 1998; Dewar *et al.*, 2003).

Whilst some economic aspects of environmental improvements, such as the Stewardship scheme for preceding stubbles, have been quantified, weeds in GMHT could allow sugar beet to be managed for environmental benefit. It shoud be possible to increase the number of invertebrates (Dewar *et al*., 2003) and/or weed seed for birds in the autumn (Dewar *et al*., 2002), by using band spray systems. Whilst this could further improve the environmental impact of sugar beet, on areas where it was used it would be at a small expense in potential yield and is likely to obviate the 5% increase in yield referred to above.

A range of other, unquantifiable, benefits exist and these include the reduction in early morning spraying at unsociable times of the day, the release of management time, the reduction in pesticide use, the potential to manage for wild-life and reductions in tractor hours and consequently energy inputs. Benefits could also result from reductions in weed control in cereals, because this might increase the number of weeds that survive to provide bird food or habitat in the subsequent stubble. The risks to ground nesting birds from tractor hoeing would be removed by the change to GMHT beet.

The annual average national benefit of £154 ha^{-1} (or £23 million yr^{-1}) summarised in Table 1 shows the general benefit to the industry. Therefore one of the major losers from the introduction of GMHT beet would be the agrochemical industry involved in the production or distribution of conventionally used agrochemicals. The final column in Table 1 shows where some growers could gain more, although it is extremely unlikely that all the maximum savings listed would be available on any one farm. It should also be noted that not all farms would benefit from the savings in weed control costs in beet (e.g. those only paying £29 ha^{-1} at present). However, they may well benefit from other cost savings identified here and most growers would appreciate the flexibility of weed management associated with the GMHT technology.

Growing costs of sugar beet are currently in the region of £18 t^{-1} (Leeds, 2002) and the use of GMHT would reduce this to £15-16 t^{-1}. Lower production costs would also allow beet to be grown for ethanol production with less need for public funded tax breaks.

Whether GMHT sugar beet is grown in the UK in the future will depend on political decisions and the results from experiments, including the DEFRA Farm Scale Evaluations (Firbank *et al*., 1999) that are due to report in 2003. However, the profitability

of sugar beet (Lang, 2002) has fallen in recent years and is likely to decrease further. Price reductions are expected when the sugar regime is reformed and the Everything but Arms agreement (an EU initiative to allow least developed countries to export sugar to the EU) comes into force in 2006. Sugar beet production is an important part of arable rotations and provides a range of environmental benefits to the areas where it is grown (Anon., 2002*d*). GMHT beet would allow sugar beet to be produced at lower prices than currently and allow beet to continue to be grown in the UK.

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