Gene flow and the practical management of genetically modified crops in the UK

J H Orson
Morley Research Centre, Morley St. Botolph, Wymondham, Norfolk, NR18 9DB, UK

J F Oldfield
Raynham Farms Co. Ltd., East Raynham, Fakenham, Norwich, Norfolk, NR21 7EH, UK

ABSTRACT

Crops that are tolerant to the non-selective herbicides glyphosate or glufosinate have been used as examples to describe the possible impact of gene flow on the on-farm management of genetically modified crops in the UK. There are many practical, economic and environmental advantages that could accrue from their adoption. This is provided that there is consumer and regulatory acceptance of these crops and that any practical disadvantages of gene flow are limited. Their management to minimise the impact of gene flow will require a disciplined approach to record keeping, seed handling, crop management and crop handling and storage. It is vital that all those on the farm, including office and support staff, should be fully informed of the procedures required to handle the seed, grow the crop and handle and store the produce. It is concluded that the ease with which gene flow is managed in order to meet grower, consumer and regulatory requirements will help to determine the extent of the adoption of herbicide tolerant crops and any consequent economic and environmental benefits.

BACKGROUND

The implications of the introduction of genetically modified crops are likely to be very profound. The first introductions into the UK will probably be oilseed rape, sugar beet, fodder beet and maize that have been modified to be tolerant to the non-selective herbicides glyphosate or glufosinate. These are used as examples in this paper on the on-farm implications of gene flow, particularly as only the guidelines for the management of herbicide tolerant crops are available at the time of writing.

UK arable production is becoming more exposed to world markets. This trend will continue with the support measures for combinable crops that are proposed under Agenda 2000. UK wheat and oilseed rape growers are becoming internationally competitive because they have invested wisely in technologies such as mechanisation, plant breeding, pesticides and chemical fertilisers. These have resulted in a fuller exploitation of a climate and soils that can sustain high yields (Orson, 1997). It is because of this experience of technology determining international competitiveness that some concern is being expressed that Europe is dragging its feet over the introduction of genetically modified crops.

Whilst UK sugar production from beet is competitive within Europe, the production from cane is significantly more competitive. Therefore, there will have to be a dramatic increase in the efficiency of European sugar beet production in the event of less protected markets.

Forage maize production in the UK has increased rapidly in recent years because of its value in rations for ruminants. Fodder beet production has been limited by the increased separation of livestock and arable production. Most livestock farms do not have the expertise to manage the complexity of weed control using conventional herbicides.

The lower product prices over the last two seasons are resulting in radical changes on arable farms. Variable costs have been minimised and fixed costs reduced by thoroughly reviewing every cost, increasing the scale of production, and machinery and labour rationalisation and sharing. There is now little scope for further reductions in the variable costs of producing conventionally bred cultivars of arable and forage crops.

THE ON-FARM MANAGEMENT OF HERBICIDE TOLERANT CROPS

The management of herbicide tolerant crops will depend on several factors:

- The conditions of registration and management guidelines from the provider of the seed and/or the buyer of the produce.
- The reasons for adopting herbicide tolerant crops.
- The consequences of gene flow.

Gene flow, in the context of this paper, is defined as the transfer of herbicide tolerance to other crops of the same or related species and/or to weeds in pollen and also the movement of herbicide tolerance in seed and produce. It is acknowledged that the conditions for registration and guidelines for crop management are designed to minimise gene flow and that gene flow could also have undesirable environmental consequences.

Conditions of registration and management guidelines

The management guidelines for herbicide tolerant crops (British Society of Plant Breeders, personal communication) will result in great care having to be taken on the farm. The most demanding situation is likely to be where a small-seeded herbicide tolerant crop, such as oilseed rape, is being grown on the same farm as 'conventionally bred' cultivars. This will be particularly so where there is a requirement to segregate the produce of modified crops and to minimise the spread of herbicide tolerance to other fields. In such a situation, at least initially, the extent of the management required to ensure segregation might be determined by the standards imposed for 'GM-free' produce by buyers rather than those standards imposed by the regulatory process.

Management guidelines may involve some or all of the following, depending on regulatory requirements, crop species, objectives of the grower, the standard of segregation required and end-user requirements:

- Recognition of isolation distances.
- Recording of receipt and safe and separate storage of seed and its protection from vermin.
- Preventing seed spills during transport about the farm, re-sealing of bags containing unused seed, cleaning out seed drills and the cleaning up, recording and monitoring of seed spills.
- Eliminating seed production by hand roguing.
- Avoiding leakage of the produce of genetically modified crops during transport. Trailers will have to be sealed and probably covered. Handling equipment, such as grain elevators,

will have to be cleaned prior to handling 'conventional' produce and in-field spills and spills in the vicinity of the stores will have to be cleaned up and recorded.

- Matching the area of production to storage facilities to ensure separate storage from the produce of conventional varieties. This may cause difficulty in some cases when there is a significant isolation distance required between commercial herbicide tolerant crops and commercial conventionally bred crops.
- Thoroughly cleaning stores and handling equipment after use.
- Restricting movement of herbicide tolerant seed in harvesting and cultivation equipment. The problems associated with the prevention of the movement of the seed of small-seeded crops, such as oilseed rape, around the farm are of great practical significance. Cleaning out combines and cleaning tyres and cultivation equipment is very time consuming and conflicts with the commercial necessity of minimising the costs of labour and machinery.
- Adopting practices to minimise the number of volunteers and their control in subsequent crops.
- Keeping meticulous and accurate field records and providing a robust and effective audit trail of records to prove that the above has been carried out. This task should not be underestimated and sound preparation will be necessary to ensure that all aspects of the management of these crops are carried out and recorded to the required standards at a time when labour may be under significant time pressure.
- Providing information on all aspects of the management of genetically modified crops and the possible consequences of failing to meet management guidelines to every person who works on the farm, including office and other support staff. This is absolutely essential and, in the view of the authors of this paper, the responsibility of those selling the seed.

Isolation distances from neighbouring crops on adjoining farms may be a cause of difficulty and discussions between farmers should start at the earliest possible stage. There could be friction between neighbouring farmers where an end-user specifies greater isolation distances than the regulatory requirements in order to claim its products are 'GM-free'. It has been suggested that where isolation requirements are not very demanding, an isolation strip could be sown with a conventional cultivar, but the separate requirement for weed control is not compatible with the farmers' requirement to reduce labour and machinery on farms. However, such a strip would also serve as an area to help purge combines of herbicide tolerant seeds; the success of this will depend on the level of gene flow into this area.

The reasons for adopting herbicide tolerant crops

Meeting specific agronomic requirements

Initially, it is envisaged that the crops will be introduced to meet specific agronomic requirements that could include:

- Control of perennial weeds.
- Control of troublesome 'annual' weeds such as volunteer potatoes and weed beet that are expensive and difficult to control in sugar beet and complexes of broad-leaved weeds which can be difficult and/or expensive to control in oilseed rape.
- To assist in preventing or managing herbicide resistant weeds.

These objectives may also influence the time when glyphosate and glufosinate is applied to the herbicide tolerant crop. For instance, it may be preferable to use selective herbicides in glyphosate tolerant crops until some specific target weeds, notably perennial broad-leaved weeds such as creeping thistle, have reached a development stage when they will transport the glyphosate to the perenniating organs.

Increasing profits

Farmers will do their own cost/benefit analysis when deciding whether to adopt herbicide tolerant crops. Herbicide tolerant crops will have to produce, at a minimum, similar levels of profit to conventionally bred crops. The indirect benefits to take into account include reduced weed control costs through the rotation as well as reductions of fixed costs due to increased flexibility in the time of application of herbicides when compared to conventionally bred cultivars. The additional costs will include higher seed costs and/or technology fees as well as those involved in complying with management guidelines.

Herbicides are currently a very significant variable cost in sugar and fodder beet and herbicide tolerance offers the prospect of significant reductions in the cost, ease and flexibility of weed control. Also, independent research has suggested that herbicide tolerant crops of beet treated with glyphosate are higher yielding than when treated with selective herbicides (Wevers, 1998). Herbicide tolerance may also result in an increase in the area of fodder beet grown in livestock areas because less expertise is required for weed control. All this, plus the fact that pollen production should be eliminated by removing flowering plants i.e. bolters during the season, suggests that there could be rapid adoption of herbicide tolerant beet crops. This is based on the assumption that there will be consumer acceptance of the technology and that herbicide tolerant cultivars will have a similar yield potential to conventionally bred cultivars.

Improving the environmental value of arable land

One of the major objections to the adoption of herbicide tolerant crops is that there will be fewer weeds in the crop resulting in less biodiversity. On the other hand, the ability to manage, both easily and cheaply, weeds in every crop within the rotation will provide more opportunity to leave uncompetitive populations to grow, flower and set seed thus benefiting in-crop biodiversity. Farmers could also adopt strategies in herbicide tolerant beet to encourage biodiversity such as delaying weed control or leaving narrow unsprayed strips in the field to meet prescribed targets every year. With conventional herbicides, there is a variation from year to year in the number of weeds at harvest. However, weed numbers are usually very low because farmers have to adopt an insurance approach with conventional herbicides because the levels of control are less predictable than with glyphosate and glufosinate.

There are other environmental advantages that can be envisaged:

- Preventing resistance to selective herbicides and controlling 'difficult weeds' will reduce herbicide usage through the rotation.
- Reducing the threat of resistance to selective herbicides and increasing the options for perennial weed control may result in the re-introduction of non-plough tillage with its attendant benefits of reduced costs, reduced erosion and an increase in over-wintered stubble. The latter will also improve the food chain for farmland birds.

- Controlling perennial weeds that have spread from habitats on headlands that have been introduced and managed in order to encourage biodiversity. This would remove one of the major concerns about allowing perennial weeds to thrive on the edge of fields.
- Glyphosate and glufosinate are more environmentally benign than some herbicides. Their use in maize will reduce the use of atrazine. Atrazine still occurs regularly in water.

The consequences of gene flow

Volunteers

The implications of herbicide resistant volunteers will have to be judged on an individual herbicide and crop species basis. For instance, glyphosate tolerant volunteer potatoes will be very difficult to control through the rotation because one of the most effective control measures is pre-harvest applications of this herbicide in a range of crops, notably cereals.

The volunteers of the crops in question should not cause a significant control problem later in the rotation. They are equally susceptible to conventional herbicides used in other crops and should not cause significant problems in between-crop management. However, the increased priority for their control may influence herbicide choice and timing in the other crops in the rotation.

It is essential that the number of volunteers are minimised through careful harvesting, control of pollen production from herbicide tolerant sugar or fodder beet and care with post-harvest cultivations.

Sugar beet is a biennial and if drilled too early will vernalise and bolt i.e. set seed. Hence, herbicide tolerant crops should not be sown too early in the spring. It should be noted that the current method for controlling high numbers of bolters is to use a rope wick to apply glyphosate. This option will not be available in a glyphosate-tolerant crop. Another form of herbicide tolerance could be used in the subsequent sugar beet crop to help ensure that volunteers tolerant to the herbicide used in the previous tolerant crop are controlled.

The seed shed from oilseed rape will be reduced where stem canker has been controlled and the crop matures evenly, favouring the production of herbicide tolerant crops in fields with little variation in soil types. It should be noted that glyphosate or glufosinate would not be available to desiccate the crop before harvest where the crop is tolerant to one of these herbicides, although diquat may be used on either modification. Research has shown that leaving shed seed of oilseed rape on the soil surface for three to four weeks after harvest will dramatically reduce the number of volunteers in following crops (Pekrun *et al.*, 1998).

The consequences of gene flow to other species

Extensive gene flow to botanically similar weeds will reduce the efficiency of weed control of the non-selective herbicides but it must be pointed out that farmers will not be worse off than they were before the introduction of herbicide tolerant crops. This is because most weeds, including some 'problem' weeds, will remain susceptible to the non-selective herbicides and farmers can always revert back to selective herbicides. However, those species which are botanically similar to the crop are the ones which are often the most difficult to control with selective herbicides. There is also the possibility that selective herbicides may be withdrawn from the market because of herbicide tolerance restricting their sales. The inability to control the weeds that have become resistant to the non-selective herbicides may also cause limited problems in between-crop management.

It is most unlikely that weeds will develop resistance to glyphosate or glufosinate. There are instances of glyphosate resistance in *Lolium rigiditum* in Australia (Powles *et al.*, 1998). However, it should be pointed out that this species has a propensity to develop herbicide resistance and the usage of glyphosate involved in these instances will not be matched in this country, unless every crop is treated with the herbicide.

CONCLUSIONS

There will be advantages from the limited adoption of herbicide tolerant crops where there is the requirement to control perennial weeds or difficult weeds in specific fields. However, to exploit fully any economic and environmental advantages will require a very significant adoption of these crops. Assuming there is end-user and regulatory acceptance, the ease with which gene flow is managed will not only help to determine the extent of their adoption and any consequent economic benefits but also the extent of any environmental benefits. Therefore, it is likely that the environmental advantages from the adoption of herbicide tolerant sugar and fodder beet and herbicide tolerant maize, where gene flow should be more easily controlled, will be more rapidly achieved.

This paper has discussed the implications of gene flow on the crop management of herbicide tolerant crops. It is clear that these have to be considered on a case by case basis. Similarly other transgenes in individual crop species and their potential for and impact on gene flow would also have to be considered on a case by case basis.

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