The use of hormone herbicides for resistance management and control of difficult weeds in cereal crops in the UK (with special reference to Scotland)

Resistenzmanagement und Bekämpfung von Unkräutern in Getreide in Großbritannien durch Anwendung von Phenoxyherbiziden (unter besonderer Berücksichtigung von Schottland)

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Summary

This paper reviews the importance of phenoxy herbicides (hormone herbicides) in Scottish Agriculture with specific reference to the spring barley crop, the most important cereal crop in Scotland. In 2013 the agricultural census figures showed that to 296,000 hectares of spring barley were planted in 2013. Of this area pesticide usage surveys estimate that 72% of the spring barley crop was sprayed with a metsulfuron-methyl, (sulfonylurea/ALS inhibitor), the most common sulfonylurea in Scotland in 2012. There was a similar area of crop sprayed with a phenoxy herbicide, a figure that has remained fairly constant over the last 10 years. The phenoxy herbicides are important as standalone products but they also have an important use in resistance management of the sulfonylurea herbicide group. Sulfonylureas are the foundation of herbicide use in the spring barley crop in Scotland. The use of phenoxy herbicides in spring barley has not prevented the development of resistant to the sulfonylureas in the *Stellaria media* (common chickweed) population in the Scottish spring barley crop. Sulfonylurea resistant chickweed is not confined to the spring barley crop but is a problem in other crops in Scotland such as potatoes and maize where sulfonylureas are used. Resistance to the sulfonylurea group of herbicides has been shown to be target site occurring as result of a single mutation. The multi site mode of action of the phenoxy herbicides are useful anti-resistance options with the sulfonylureas offering control of sulfonylurea resistant *Stellaria media*. The phenoxy herbicides are also particularly useful in increasing the weed spectrum of the sulfonylureas and the use to control difficult weeds such as *Fumaria officinalis* (common fumitory) in spring barley crop.

Keywords: ALS, chickweed, phenoxy herbicides, Scotland, resistance, spring barley

Zusammenfassung

In diesem Beitrag wird die Bedeutung von Phenoxyherbiziden in der schottischen Landwirtschaft unter besonderer Berücksichtigung des Anbaus von Sommergerste betrachtet. Sommergerste ist die wichtigste Getreidekultur in Schottland. Landwirtschaftliche Erhebungen aus dem Jahr 2013 zeigen, dass insgesamt 296000 Hektar Sommergerste angebaut wurden. 72 % dieser Fläche wurde mit Metsulfuron-methyl (Sulfonylharnstoff/ALS-Hemmer) behandelt, dem im Jahre 2012 am häufigsten angewendeten Sulfonylharnstoff in Schottland. Eine vergleichbare Anbaufläche, die in den letzten 10 Jahren unverändert blieb, wurde mit Phenoxyherbiziden behandelt. Phenoxyherbizide sind von großer Bedeutung als Soloprodukte und spielen eine große Rolle im Rahmen des Resistenzmanagements bei Sulfonylharnstoffen. Sulfonylharnstoffe sind die Grundlage der Unkrautbekämpfung in Sommergerste in Schottland. Die Anwendung von Phenoxyherbiziden in Sommergerste hat jedoch die Entwicklung von Sulfonylharnstoff-Resistenzen bei *Stellaria media*-Populationen in Schottland nicht verhindert. Diese Resistenzen sind nicht beschränkt auf Sommergerste, sondern kommen auch in anderen Kulturen wie Kartoffeln und Mais vor. Es konnte gezeigt werden, dass es sich bei den Sulfonylharnstoff-Resistenzen um eine wirkortspezifische Resistenz handelt, die durch eine einzelne Mutation hervorgerufen wird. Die breite Wirkungsweise der Phenoxyherbizide ist eine Option im Resistenzmanagement bei der Bekämpfung resistenter *Stellaria media*-Poplationen. Phenoxyherbizide erweitern zudem das Unkrautspektrum der Sulfonylharnstoffe, insbesondere zur Bekämpfung von Problemunkräutern wie *Fumaria officinalis* in Sommergerste.

Stichwörter: ALS, Phenoxyherbizid, Resistenz, Schottland, Sommergerste, *Stellaria media*

Introduction

The sulfonylurea or (ALS inhibitor) group of herbicides play an important role in cereal crops in Scotland, especially spring barley. The spring barley crop area in Scotland was 296,000 ha (SCOTTISH AGRICULTURE CENSUS, 2013). Figures obtained from the Scottish pesticide usage survey in 2012

showed that 70% of the spring barley crop was treated with thifensulfuron, 74% received metsulfuron-methly and 72% was treated with a phenoxy herbicide mecoprop-p. About 200,000 ha of cereal crop received a phenoxy herbicide in Scotland in 2012 (PESTICIDE USAGE SURVEY SCOTLAND, 2012, SCOTTISH AGRICULTURAL SCIENCE AGENCY, SASA 2012). Both groups of herbicides are largely used to control broad-leaved weeds. Although a high level of phenoxy herbicides are used in spring barley. The statistics show that sulfonylureas are not always used with a tank-mix partner herbicide with a different mode of action. Either 28% of the crop is sprayed with a straight sulfonylurea or does not get sprayed at all.

The extensive use of acetolactate synthase (ALS) herbicides in numerous forms, co-formulations and trade names has lead to the increase in resistant biotypes types of chickweed (*Stellaria media*) in Scotland and in England resistant poppy (*Papaver rhoeas*). Indeed resistant poppy is now wide spread in Europe (MOSS, 2004). Resistance to the sulfonylureas was first discovered in 1987 (SAARI ET AL., 1992). There is evidence that resistance to ALS inhibitors is now appearing in other broad-leaved species in Scotland such as Mayweeds (*Matricaria*). ALS inhibitors, as the sulfonylurea group of herbicides, are applied to crops across the rotation in Scotland. They are the foundation for weed control in spring barley, the most important crop in Scotland with over 290,000 hectare grown in 2013 (SCOTTISH AGRICULTURE CENSUS, 2013). In winter cereals sulfonylureas are used in the autumn to broaden the broad-leaved weed control of residual herbicides and in the spring to tidy up broad-leaved weeds.

An independent survey in 2011 confirmed > 40 cases across the UK including Northern Ireland, (Moss *et al*., 2011), although the agrochemical trade believe the cases of chickweed resistance to be greater than officially confirmed. This resistance was identified as target site not enhanced metabolism as occurs in grass weeds Resistant populations of *Papaver rhoeas* are more important in England, less in Scotland. There are now indications that there may be resistance in mayweed, (*Matricaria* spp.) although this has not been officially confirmed. There is a tendency on farm to use too low a rate of sulfonylurea which can cause mayweeds to regrow.

In potatoes there is a sulfonylurea for post emergence use to control broad-leaved weeds including chickweed and mayweeds (*Matricaria* spp.).

There is also a sulfonylurea awaiting approval for use in winter rape which will target chickweed another broad-leaved weeds. As well as targeting broad-leaved weeds the sulfonylureas herbicides are also widely used to control grass species in Scotland, mainly annual meadow grass (*Poa annua*) and *Bromus* species. However what is not often realised is that most of these products also control chickweed and mayweeds increasing the selection pressure.

Studies have shown that the resistant mechanism of sulfonylureas to broad-leaved weeds is target site. At least two mutations in *S. media* have been characterised, Pro-197-G and Trp0574 (MARSHAL *et al*., 2010). There is no evidence of enhanced metabolism mechanisms that is common in grass weeds. There is no evidence of cross resistance to other herbicide groups.

Why has resistance to sulfonylurea herbicides occurred in broad-leaved weeds occurred in Scotland and elsewhere?

Over use

The first case of sulfonylurea resistance in Scotland was identified in 2000 (MOSS *et al*., 2011). Scottish Agricultural Science Agency (SASA) agency statistics for the year 2000, as shown in Table 1, indicate that 60.5% of the Scottish spring barley crop was sprayed with the sulfonylurea metsulfuron-methyl rising to 72.5% in 2012. The corresponding amount of phenoxy herbicide, (mecoprop-p mecoprop, MCPA and MCPB) used in the period 2000 to 2012 fluctuates, from 83% in 2000 and 72.24% in 2012, a decrease of 13%.

Although a slight decline in use, phenoxy herbicides they still have a good market share, being promoted as a tank-mix option with the sulfonylureas. It is recognised they have a different mode of action to the sulfonylureas. They are translocated in the plants phloem affecting many parts of

the plants metabolism including photosynthesis, respiration and nitrogen uptake (ROBERTSON and KIRKWOOD, 1970). The sulfonylureas on the other hand work on a single point ALS gene in the meristemic tissue. Thus the combination of a sulfonylurea and a phenoxy herbicide is a good anti resistance strategy protecting the sulfonylurea group and broadening the weed spectrum.

The area of spring barley treated with (fluroxypyr) increased from a base in 2002 of 2.52% to nearly 18% in 2012. Added to the 72% treated with a phenoxy herbicide gives an area of 90% of the crop treated. This increase in fluroxypyr corresponds to promotion of products alongside the phenoxy herbicides for use with sulfonylureas as anti-resistance strategy.

Tab. 1 Percentage (%) herbicide use on spring barley for the years 2000-2012. (Scottish Agricultural Science Agency Product Usage Survey).

Tab. 1 *Herbizidanwendung (%) in Wintergerste der Jahre 2000-2012.* (Scottish Agricultural Science Agency Product Usage Survey).

year	*total ha SB*	*% phenoxy**	*% thifensulfuron*	*% metsulfuron*	*% fluroxypyr*
2000	255	83	50	60.46	
2002	264	74.75	56	60.54	2.52
2004	259	84.59	64	71.84	1.38
2006	220	79.86	57	51.65	2.9
2008	262	70.42	68	58	2.87
2010	242	64.35	70	64	10
2012	289	72.24	70	72.5	17.93

*includes MCPA and MCPB

Improper use

There is no doubt that sulfonylureas are not always used in Scotland with a partner product such mecoprop-p. There are many reasons for this. The increase in cost is certainly a factor. The weed spectrum that modern sulfonylurea mixes offer can be attractive negating the extra cost of an additional phenoxy herbicide. Sulfonylureas are often sold in combination, e.g. Harmony M, (metsulfuron-methyl+thifensulfuron) which gives a good weed spectrum. However even these products miss out on important weeds. The addition of a phenoxy herbicide such as mecoprop-p improves control of important weeds such as *Fumaria officinalis*, *Polygonum* species, *Galium aparine, Gliosis tetrahit*, all important weeds in Scottish Agriculture. Another often neglected phenoxy herbicide MCPA provides useful control of another common weed in spring cereals, *Cirsium vulgare* as well as controlling *Galeopsis tetrahits.*

Spring barley usually suffers from manganese deficiency at the young plant stage. Historically the cheaper formulations of manganese sulphate did not mix well with phenoxy herbicides so that they were often omitted from the mix so that the sulfonylureas were often applied as single products. Now with better formulations of manganese there is not a tank-mix problem and no barrier to the use of phenoxy herbicides in complex tank-mixes.

In conclusion the phenoxy herbicides have maintained there market share of the Scottish spring barley market since 2000 (Tab. 1) and will perhaps increase if cases of recorded sulfonylurea resistant chickweed continue to rise.

Phenoxy herbicides and control of difficult weeds in Scotland.

Common Fumitory (*Fumaria officinalis*) is becoming an important weed in crop rotation in Scotland. It has been the increasing partly due to the wide spread use of diflufenican in winter cereal crops, which controls a wide spectrum of weeds of broad-leaved weeds but not *Fumaria*

officinalis. Fumitory can be controlled by mecoprop–p but only at a high rate. Often the application rate used is not high enough, allowing the Fumitory to regrow as shown in Table 2. Trials and commercial practice has shown the rate of mecoprop-p needs to be a least 1.0 L/ha for complete kill. The issue is compounded by the fact that there are other species of *Fumaria officinalis* and *Fumaria capreolata* (white ramping Fumitory), which appears to be less tolerant to phenoxy herbicides.

Tab. 2 Control of *Fumaria officinalis* (Fumitory) in spring barley at a site Scotland. The benefits of phenoxy herbicides.

Tab. 2 *Bekämpfung von Fumaria officinalis* in Sommergerste auf einem Schlag in Schottland. Vorteile der Phenoxyherbizide.

	Fumitory control 34 DAT
Untreated (7 plants/m^2)	0
Spitfire, (fluroxypyr + florasulam) 0.75 L	30.4
Spitfire 0.75 L+Duplosan KV (mecoprop-p) 1.0 L	100
Spitfire 0.75 L+HBN (Ioxynil+Bromoynil) 0.75 L	47.8
Galaxy (clopyralid + fluroxypyr + clopyralid) 1.0 L	1
Galaxy 1.0 L + Duplosan 1.0 L	100
Galaxy 1.0 L + HBN 0.75 L	30.4
Spitfire 0.75 L+ Saxon (Dicamba + Mecoprop-p) 0.75 L	82.6
Spitfire 0.75 L+ Dicamba + Duplosan KV1.0 L	100
Harmony M 50G + Duplosan 0.5 L + HBN 0.5 L	82.6
Harmony M 50G+ MCPA1.0 L	65
Refine Max 56G (metsulfuron-methyl + thifensulfuron) + Saxon 0. 75 L	82.6

The choice of phenoxy herbicide is important depending on weed spectrum. MCPA was shown in this trial to be not the product of choice. However MCPA still has a place in the Scottish spring barley crop. A small percentage of the spring barley crop is under sown with a grass clover mix. This technique is used to drill a grass/clover crop in sequence with a cereal crop in the spring so that after the cereal crop is harvested there is crop of grass for grazing. Weed control can be difficult in this scenario as clover is not tolerant to commonly used sulfonylureas plus mecoprop-p mixes. What is clover safe is the phenoxy herbicide 2,4-DB. However 2,4-DB has a limited weed spectrum and is commonly mixed with up to a litre/ha of MCPA. This type of use would account for the proportion of the spring barley sprayed with MCPA which according to SASA usage survey for 2012 amounts to 4.69 %.

Discussion

The phenoxy herbicides have a major place in the Scottish arable sector for the use as an anti resistant strategy to protect the sulfonylureas herbicides and/or increase their weed spectrum. There are new herbicide groups under development for cereal crops; in fact it is likely we will continue to lose herbicides as they fail to meet EU Annex 3 data requirements or will be up for substitution. Indeed next season farmers in Scotland will not be able to use ioxynil containing products and co-formulations such as Oxytril CM (ioxynil + bromoxynil) and chlorotoluron is under revocation and use up on farm. Both products have key broad -leaved weeds in there spectrum which will be lost. Despite being old chemistry the phenoxy herbicides have maintained their market share is perhaps a cost effective alternative to revoked and lost products?

In conclusion phenoxy herbicides still have a major place in Scottish agriculture to broaden the weed spectrum of sulfonylureas in spring barley and to control difficult weeds such as *Fumaria capreolata, Polygonum* spp. and other difficult weeds. However care needs to taken when using phenoxy herbicides in certain river catchment areas in Scotland that are used for drinking water. The relatively large use of phenoxy herbicides on spring barely has resulted in MCPA and CMPP leaching into water courses during periods of high rainfall after application. Levels higher than EU Water Framework and the Drinking Water Directive thresholds have been recorded in some seasons. It is up to all those involved in the agro-chemical supply trade to ensure that phenoxy herbicides are used sensibly, whether used alone or in tank- mix with sulfonylureas in spring barley or under sown crops. They need to be used at sensible application rates to control difficult weeds.

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