Weed populations in the main cultures of Luxembourg: control options and monitoring in a complex environmental and political framework

Unkrautpopulationen in den ackerbaulichen Kulturen Luxemburgs: Bekämpfungsoptionen und Monitoring in einem komplexen umwelt- und agrarpolitischen Umfeld

Sergiu Treer[1*], Moritz Colbus[2], Simon Steiger[2], Michael Eickermann[1], Lucien Hoffmann[1], Marco Beyer[1]

[1]Luxembourg Institute of Science and Technology (LIST), Department Environmental Research and Innovation (ERIN), 41, rue du Brill, 4422 Belvaux, Luxembourg
[2]Chambre d'Agriculture, 261 Route d'Arlon, 8011 Strassen, Luxembourg
*Corresponding author, sergiu.treer@list.lu

DOI 10.5073/jka.2020.464.008

Abstract

Due to ecotoxicological and environmental reasons, chemical treatments for weed control are under discussion. To help farmers in coping with challenges imposed by restricted herbicide availability, projects on using modified crop rotations for reducing weed pressure, digital approaches for better decision support, and a better integration of non-chemical weeding were initiated. First monitoring programs in winter oilseed rape in Luxembourg offered a preliminary overview about mainly widespread weed species like *Stellaria media, Viola arvensis, Polygonum aviculare* as well as *Poa annua, Elymus repens* and *Apera spica-venti*. *Chenopodium album* was found in moderate and high numbers in maize, as well as the spring-germinating *Polygonum* species. *Polygonum convolvulus* escaped from or re-emerged after the chemical control at location Kuborn, while *C. album* was poorly controlled by the mechanical treatments. *Alopecurus myosuroides* plants with mature seeds were almost exclusively found in the South of Luxembourg. All 35 *A. myosuroides* seedling samples tested so far were resistant towards Stomp® Aqua (containing the microtubule assembly inhibitor pendimethalin). In case of Sigma® Maxx (containing the ALS inhibitors iodosulfuron+mesosulfuron), 2 out of 35 samples were sensitive and moderately resistant, respectively. 31 samples were resistant to Sigma® Maxx. 17 out of 35 samples were sensitive to Axial® (containing the ACC-ase inhibitor pinoxaden), while 18 samples were resistant to Axial®.

Keywords: ACCase inhibitors, *Alopecurus myosuroides*, ALS inhibitors, herbicide resistance, Luxembourg, microtubule assembly inhibitors

Zusammenfassung

Chemische Unkrautbekämpfung wird aufgrund von ökotoxikologischen Bedenken diskutiert. Um Landwirten zu helfen, die Ausbreitung von Unkräutern auch bei sinkender Verfügbarkeit von Herbiziden begrenzen zu können, wurden Projekte zu modifizierten Fruchtfolgen zur Reduzierung des Unkrautdruckes, digitale Ansätze für bessere Entscheidungen zum Herbizideinsatz und zur besseren Integration von nicht-chemischen Unkrautbekämpfungsmaßnahmen begonnen. In einem ersten Monitoring in den Rapsbeständen Luxemburgs wurden relativ weit verbreitete Arten wie *Stellaria media, Viola arvensis, Polygonum aviculare* sowie *Poa annua, Elymus repens*, und *Apera spica-venti* gefunden. *Chenopodium album* wurde neben den im Frühjahr keimenden *Polygonum*-Arten in moderater bis hoher Individuenzahl im Mais gefunden. *Polygonum convolvulus* wurde nach chemischer Bekämpfung in hoher Dichte am Standort Kuborn gefunden, wohingegen *C. album* schlecht von mechanischen Methoden bekämpft wurde. *Alopecurus myosuroides*-Pflanzen mit reifen Samen wurden nahezu ausschließlich im Süden Luxemburgs gefunden. Alle 35 bislang getesteten *A. myosuroides* Sämlingsproben waren resistent gegen Stomp® Aqua (mit dem K1 Hemmstoff Pendimethalin). Im Fall von Sigma® Maxx (mit den ALS-Inhibitoren Iodosulfuron+Mesosulfuron), waren jeweils 2 von 35 Proben sensitiv bzw. moderat resistent. 31 Proben waren resistent gegenüber Sigma® Maxx. 17 von 35 Proben waren sensitiv gegenüber Axial® (mit dem ACC-ase Inhibitor Pinoxaden), während 18 Proben resistent gegenüber Axial® waren.

Stichwörter: ACCase-Inhibitoren, *Alopecurus myosuroides,* ALS-Inhibitoren, Herbizidresistenz, Luxemburg, Microtubuli-Aufbau-Inhibitoren

Introduction

After a road accident with a sprayer in neighboring Belgium in 2014, the metazachlor breakdown product 479M08 was found downstream in the largest drinking water reservoir of Luxembourg (KARIER et al., 2017). Since then, herbicide use is increasingly debated. Phasing out products containing glyphosate by 2021 is on the political agenda of Luxembourg; further restrictions of

herbicide use particularly in areas where drinking water is extracted, are targeted. Among pests, weeds are responsible for the highest potential loss of approximately 34% in major crops (OERKE, 2006).

In 2018, the official Luxembourgish Agriculture Statistics Portal (STATEC) reported a total agricultural surface, including permanent pastures, of 131559 ha of land. Out of this surface, in terms of crops, we observe a prevalence of winter cereals, with winter wheat being grown on 11863 ha, winter barley grown on 4286 ha, and winter triticale cultivated on 4669 ha. Oilseed rape, an important broadleaf crop in an otherwise cereal-dominated crop rotation, was grown on 3393 ha, as of year 2018. Maize, a crop serving the country`s livestock sector, is cultivated almost exclusively as silage maize, with a reported surface in 2018 of 14990 ha. Pastures, both perennial and in arable rotations, amounted to 67705 ha, in 2018. (Source: STATEC, 2018)

Luxembourg is located in the central zone for the EU authorization of pesticides together with Belgium and Germany. Therefore, the Luxembourgish herbicide market is dominated by products that are also registered in Belgium or Germany. Major active ingredients as they were contained in the products purchased by Luxembourgish farmers in the year 2016 are given in Tabelle 1.

Tab. 1 Major herbicides purchased by farmers in Luxembourg, 2016.

Tab. 1 *Herbizide, die in Luxemburg in den Hauptkulturen eingesetzt wurden, 2016.*

Active Ingredient*	Sum (kg)	Winter wheat (kg)	Winter barley (kg)	Triticale (kg)	Oilseed rape (kg)	Maize (kg)
Glyphosate**	12.995	2.020	540	690	355	4.385
Isoproturon***	8.180	4.280	2.435	1.010		
Terbuthylazine	5.265					5.030
Pendimethalin	4.345	1.390	960	315		770
Dimethenamid-P	3.205				765	2.325
Pethoxamide	2.585				1.595	850
Flufenacet	2.305	320	200			1.470
Prosulfocarb	1.650	420	310	175		
Metazachlor	1.085				1.065	
Diflufenican	910	490	260	115		
Mesotrione	785					745
Sulcotrione	755					730

*Source: SERVICE D'ECONOMIE RURALE (SER), 2019

**Other uses for glyphosate include potatoes (340 kg), and grassland (1445 kg).

***Isoproturon was banned in 2017

Herbicide-resistant black-grass (*Alopecurus myosuroides*) has become a problem in neighboring Belgium, France and Germany (MOSS, 2017), but no information on prevalence and spatial distribution of herbicide-resistant weed populations is available from Luxembourg, so far.

Local consultants suspect that when a herbicide did not show satisfactory performance due to the presence of a resistant weed population, a second spray may be applied, which (i) increases herbicide use and (ii) would not be needed, if the spectrum of resistance would have been known before. First assessments of herbicide-resistance were carried out in Luxembourg to minimize ineffective herbicide use by choosing products or non-chemical methods that are still efficient.

It was the purpose of this study to provide a first characterization of the weed populations found in selected major cultures in Luxembourg as a baseline for enhancing weed control with less herbicide input.

Materials and Methods

Winter Oilseed Rape. In winter oilseed rape, a survey was done during 2015 and 2016, in 3 locations in Luxembourg, these locations were Simmern (5°58´E ¦ 49°42´N), Wahl (5°53´E ¦ 49°50´N), and Reisdorf (6°16´E ¦ 49°51´N). Weed species or genera were identified based on visual assessment, aided by the field use of the Android-based app Weed ID, © BASF SE 2018.

Maize. The survey on finding major weed species in 3 maize locations was conducted during April and July 2019. These locations were Kuborn (GPS: 5° 53′ 54,5″ ¦ E 49° 52′ 28,4″ N) , Kehlen (GPS: 6° 02′ 52,8″ ¦ E 49° 40′ 20,0″ N) and Burmerange (GPS: 6° 18′ 51,6″ ¦ E 49° 28′ 50,3″ N). The sampling area was represented by 10 subsamples of 0.25 m^2 in each plot and location, using a 0.25 m^2 square frame, placed randomly across the field. Treatments and weed control actions of the maize trials are given in Table 2.

Tab. 2 Weed control actions taken in the maize trial after the first weed assessment (03/06/2019) and before the second weed assessment (08/07/2019).

Tab. 2 *Maßnahmen der Unkrautbekämpfung im Maisversuch, die zwischen der ersten (03/06/2019) und der zweiten Bonitur (08/07/2019) der Unkräuter ergriffen wurden.*

Location	Treatment	Date	Action taken
Kuborn	Farmer's choice	05/06/19	0.6 l/ha Callisto® + 0.9 l/ha Monsoon Active® + 0.7 l/ha Stomp Aqua®
	Mechanical	05/06/19	Rollstar interrow hoe + Finger hoe
		23/06/19	Rollstar interrow hoe + Finger hoe
		26/06/19	Interrow cultivator + Finger hoe
	Hybrid	23/06/19	Rollstar interrow hoe + Finger hoe
		26/06/19	Interrow cultivator + Strip sprayer 0, 3 l/ha Monsoon ® + 0,24 l/ha Callisto®
	Chemical	05/06/19	2 l Laudis ®, 300 gr Callam® / ha
Kehlen	Farmer's choice	05/06/19	1 l/ha Monsoon Active® + 0.8 l/ha Callisto® + 0.8l/ha Frontier Elite®
	Mechanical	24/06/19	Interrow cultivator + Finger hoe
	Hybrid	24/06/19	Interrow cultivator + Strip sprayer 0.3 l/ha Monsoon® + 0.24 l/ha Callisto®
	Chemical	02/07/19	0.5 l/ha Samson Extra® 60 OD + Xinca® 0.5 l/ha
Burme-	Farmer's choice	14/06/19	1.2 l/ha Monsoon Active® + 0.5 l/ha Callisto®
range	Mechanical	14/06/19	Rollstar interrow hoe + Finger hoe
		20/06/19	Rollstar interrow hoe + Finger hoe
	Hybrid	19/06/19	Interrow cultivator + Strip sprayer 0.3 l/ha Monsoon® + 0.24 l/ha Callisto®
	Chemical	14/06/19	0.5 l/ha Xinca® + 8 gr/ha Harmonie®

The chemical weed control consisted of an herbicide mix (Tab. 2) and considered weather and soil conditions as well as control thresholds of weed density. The experiment was done in 2 replicate plots having the width of the machine used for applying the treatment (at least 3 m) and a length of 50 m.

Winter Wheat: Black grass. In a separate project, 55 *Alopecurus myosuroides* seed samples were collected from Luxembourg winter cereal and maize fields between 1st July and 15th August 2019 (Fig. 1). Although repeated trips were made in the areas north of Luxembourg-City, there were no fields with sufficient presence of the target that could constitute a viable sample.

Black grass seed samples were cleaned of debris and kept in a dry and ventilated environment at 30 °C for approx. 30 days, for maximizing germination potential. A first batch of 35 *A. myosuroides* samples were allowed to germinate in the LIST greenhouse inpots (size 7x7 cm) filled with sterile soil and then up to six plants were transplanted at BBCH 10-11 into plastic pots (size 7x7 cm) containing a standard potting soil mixture (SEMFLOR® Blumenerde, Torf- und Humuswerk Uchte, Darlaten 65-69, D – 31600 Uchte, Germany). These pots were kept in the greenhouse at field capacity with bi-weekly irrigation regimes, until the plants reached the desired growth stage. The herbicides were applied with a water volume of 250-300 l/ha. (Tukan® 1600E electric backpack sprayer - TUKAN®, Därmannsbusch 7, 58456 Witten, Germany) operated at 2,5 BAR. The product application was made on 03.09.2019 using a flat spray nozzle (110°) delivering a medium spray quality. Application was timed to the plants reaching label-recommended growth stages, at field rate and triple the field rate, using three types of herbicides, ALS-inhibitor iodosulfuron+mesosulfuron (Sigma® Maxx, Bayer Crop Science SA-NV, J.E. Mommaertslaan 14, 1831 Diegem (Machelen), Belgium; ACCase- Inhibitor pinoxaden (Axial®, Syngenta UK Limited, CPC4, Capital Park, Fulbourn, Cambridge, CB21 5XE, UK), and a the microtubule assembly inhibitor pendimethalin (Stomp® Aqua,

BASF plc, Crop Protection, PO Box 4, Earl Road, Cheadle Hulme, Cheadle, Cheshire SK8 6QG, UK). Herbicide application was done with the majority of the plants at growth stage BBCH 14.

The tests to determine herbicide sensitivity were done using the protocols developed by PANOZZO et al. (2015). Data was collected on 24.09.2019, estimating the aboveground green biomass of the plants as a measure of product efficacy, while comparing it with untreated standards of each sample.

Results

Winter Oilseed Rape. *Chenopodium album, Stellaria media, Polygonum convolvulus* and *Matricaria inodora* were all found in moderate and high numbers in most of the winter oilseed rape fields, during 2015 and 2016 growing seasons (Tabs. 3, 4). As grass representatives, only *Apera spica-venti* was found in Simmern in 2016 and in a smaller number in Wahl in 2016 (EICKERMANN et al., 2016).

Maize. *Chenopodium album* was found in moderate and high numbers in all three maize fields, as well as the spring-germinating *Polygonum* species (Tab. 5). In Kehlen, grasses were present as well, although traditionally weeds like *Alopecurus myosuroides* germinate in autumn, there were significant numbers germinating in spring as well.

Tab. 3 Major weed species in three winter oilseed rape fields in Luxembourg, 2015. The number of plants per square meter at the beginning of autumn is given.

Tab. 3 *Unkrautarten, die in drei Rapsfeldern in Luxemburg im Jahr 2015 aufgetreten sind. Es ist die Anzahl der Pflanzen pro Quadratmeter Anfang Herbst angegeben.*

	Simmern	Wahl	Reisdorf
Apera spica-venti	-	-	0.6 pl/m²
Fumaria sp.	-	0.6 pl/m²	11 pl/m²
Matricaria inodora	-	1.3 pl/m²	-
Myosotis arvensis	-	5 pl/m²	-
Papaver rhoeas	-	2 pl/m²	-
Poa annua	4.6 pl/m²	-	-
Polygonum aviculare	0.5 pl/m²	-	-
Polygonum convolvulus	-	120 pl/m²	-
Sinapis arvensis	0.67 pl/m²	-	1 pl/m²
Stellaria media	12 pl/m²	47 pl/m²	2 pl/m²
Viola arvensis	10 pl/m²	7 pl/m²	-
Volunteer cereals	2.6 pl/m²	-	-

Tab. 4 Major weed species in three winter oilseed rape fields in Luxembourg, 2016. The number of plants per square meter at the beginning of autumn is given.

Tab. 4 *Unkrautarten, die in drei Rapsfeldern in Luxemburg im Jahr 2016 aufgetreten sind. Es ist die Anzahl der Pflanzen pro Quadratmeter Anfang Herbst angegeben.*

	Simmern	Wahl	Reisdorf
Apera-spica venti	6.8 pl/m²	-	0.4 pl/m²
Chenopodium album	28.8 pl/m²	-	0.4 pl/m²
Elymus repens	14.8 pl/m²	3.2 pl/m²	-
Fumaria sp.	4.4 pl/m²	-	-
Matricaria inodora	-	0.8 pl/m²	-
Papaver rhoeas	1.2 pl/m²	-	2.8 pl/m²
Polygonum aviculare	9.2 pl/m²	-	1.2 pl/m²
Poa annua	11.6 pl/m²	-	-
Stellaria media	3.6 pl/m²	14.4 pl/m²	7.2 pl/m²
Sonchus sp.	-	-	0.4 pl/m²
Viola arvensis	10 pl/m²	-	-

Due to huge variability in the initial weed density and composition between locations and treatments in the maize trials, comparisons of the situation before weeding and after the main weeding were made. The percentage of soil that was covered by weeds increased between June

and July, except for the chemical treatment in Burmerange, where it decreased (Fig. 2). The smallest increase in weed coverage was observed in the treatment "Farmer's choice" at all test sites (Fig. 2). Mechanical weeding allowed the largest increase in weed coverage between June and July (Fig. 2).

The hybrid strategy (mechanical weeding with reduced herbicide use) limited weed expansion to a similar extend like the "Farmer's choice". A relatively poor performance of the chemical weeding was observed in Kuborn. There, *Polygonum convolvulus* escaped or re-emerged after the chemical control. Also at Kuborn, *Chenopodium album* was poorly controlled by the mechanical treatments. The strong increase in weed coverage in the mechanical treatment in Burmerange was caused by *Chenopodium album, Polygonum aviculare, Polygonum convolvulus* and *Stellaria media*.

Tab. 5 Major weed species in three maize fields in Luxembourg, 2019. The number of plants per square meter at the beginning of June is given. Small seedlings were counted, while at a later stage, weed coverage was estimated as percentage ground cover (% gc).

Tab. 5 *Unkrautarten, die in drei Maisfeldern in Luxemburg im Jahr 2019 aufgetreten sind. Dargestellt ist die Anzahl der Pflanzen pro Quadratmeter Anfang Juni. Keimlinge wurden gezählt, für größere, ineinander verwachsene Pflanzen wurde der bedeckte Flächenanteil (% gc) geschätzt.*

	Kuborn	**Kehlen**	**Burmerange**
Atriplex prostrata	-	0-80% gc	-
Alopecurus myosuroides	-	20-40 %gc	-
Bromus spec.	-	6-200 pl/m^2	0 pl/m^2
Chenopodium album	3-27 pl/m^2	4-200 pl/m^2	8-80 pl/m^2
Echinochloa crus-galli	-	0-40% gc	-
Fumaria officinalis	2-8 pl/m^2	-	-
Galium aparine	4-40 pl/m^2	-	-
Matricaria inodora	-	-	4-36 pl/m^2
Polygonum aviculare	2-10 % gc	-	4-48 pl/m^2
Polygonum convolvulus	4-24 pl/m^2	-	4-44 pl/m^2
Polygonum persicaria	-	2-20 % gc	-
Stellaria media	2-16 pl/m^2	-	4-20% gc
Veronica persica	-	-	4-68 pl/m^2
Viola arvensis	4-92 pl/m^2	-	-

Winter Wheat: Black grass. Most black grass seed samples originated from the south of the country, due to the prevalence of the target in this area. The first batch of 35 samples tested in the herbicide resistance assay confirmed previous observations by consultants in the field, that widespread herbicide resistance to the main herbicide groups mentioned above was also present in the Luxembourg populations of *Alopecurus myosuroides*. The tested products showed poor efficacy even at three times the field rate, in some cases.

All samples were resistant towards Stomp® Aqua (containing the K1 inhibitor pendimethalin) (Tab. 6). In case of Sigma® Maxx (containing the ALS-inhibitors iodosulfuron+mesosulfuron), 2 out of 35 samples were sensitive and moderately resistant, respectively (Tab. 6). 31 samples were resistant to Sigma® Maxx. 17 out of 35 samples were sensitive to Axial® (containing the ACC-ase inhibitor pinoxaden), while 18 samples were resistant to Axial® (Tab. 6).

Discussion

The weed species found in our maize and winter oilseed rape fields were rather similar, with both crops hosting the broadleaves *Stellaria media, Polygonum convolvulus, Chenopodium album, Viola arvensis and Matricaria inodora.* Most weed populations found in both crops do not represent niche or problematic, insensitive species, and therefore control should be based on robust and well-timed post-emergence herbicide choices, with broad spectrum of activity. The strong spread of *P. convolvulus* in the chemical treatments ("Farmer's choice" as well as "Chemical") in the maize field at Kuborn calls for an additional resistance test of the local *P. convolvulus* population.

The poor control efficacy of *C. album* by the mechanical treatments in maize indicates that further innovation is needed here. The mostly annual broadleaf weed species found in maize could be controlled by post-emergence positioning.

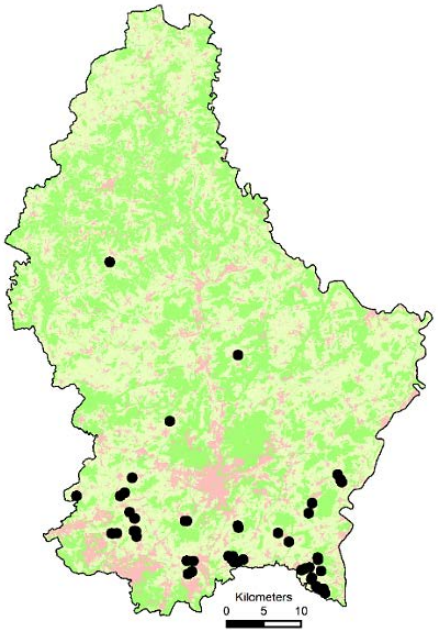

Fig. 1 Locations from which *Alopecurus myosuroides* seed samples were obtained between 1st July and 15th August 2019 in Luxembourg.

Abb. 1 *Orte, an denen Alopecurus myosuroides Samenproben im Zeitraum zwischen dem 1. Juli und dem 15. August 2019 in Luxemburg genommen wurden.*

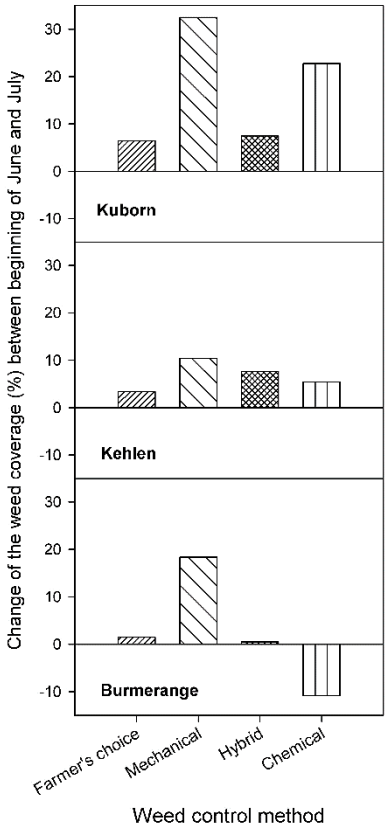

Fig. 2 Change of percentage of soil covered by weeds between the beginning of June and July at the three maize locations. For the description of the weed control methods, please see "Materials and Methods".

Abb. 2 *Veränderung des Unkrautbedeckungsgrades zwischen Anfang Juni und Juli in den drei Maisbeständen. Die Beschreibung der Bekämpfungsstrategien ist in „Material und Methoden" zu finden.*

The HRAC F2 group of triketones, namely mesotrione, is available in Luxembourg. Another option for broadleaf control can be fluroxypyr, of the HRAC O group of synthetic auxins. Annual grasses, although present in our monitoring results, do not represent a target species, at the current infestation levels. In addition, due to the unpredictable, and often dry and hot spring weather in Luxembourg, pre-emergent sprays in maize should be avoided, as product efficacy is conditioned by soil moisture.

Herbicide efficacy against black grass *(Alopecurus myosuroides)* was poor across Southern Luxembourg. Control options here can be explored based on crop rotation, namely involving spring crops such as maize, to potentially avoid the germinating period of black grass, which takes place

in autumn, or broadleaf autumn crops, such as winter oilseed rape. Benefitting from the cold and wet winters in Luxembourg, these two above-mentioned products will find good performing conditions, consistent with label recommendations. The rare occurrence of black grass from the northern cantons in 2019 is not explained at this moment, and will constitute the subject of further research.

Tab. 6 The resistance status of *Alopecurus myosuroides* seedlings obtained in Luxembourg, 2019.

***Tab. 6** Resistenzstatus der Alopecurus myosuroides Sämlinge aus Luxemburg, 2019.*

Canton	Sigma® Maxx (2 g/L iodosulfuron-methyl + 10 g/L mesosulfuron-methyl)	Stomp® Aqua (455 g/L pendimethalin)	Axial® (100 g/L pinoxaden)
Remich	MR	R	R
Remich	MR	R	R
Esch-sur-Alzette	R	R	R
Esch-sur-Alzette	R	R	R
Esch-sur-Alzette	R	R	R
Esch-sur-Alzette	R	R	R
Esch-sur-Alzette	R	R	R
Luxembourg	R	R	R
Remich	R	R	R
Remich	R	R	R
Remich	R	R	R
Remich	R	R	R
Remich	R	R	R
Remich	R	R	R
Remich	R	R	R
Remich	R	R	R
Remich	R	R	R
Esch-sur-Alzette	S	R	R
Esch-sur-Alzette	R	R	S
Esch-sur-Alzette	R	R	S
Esch-sur-Alzette	R	R	S
Esch-sur-Alzette	R	R	S
Esch-sur-Alzette	R	R	S
Esch-sur-Alzette	R	R	S
Esch-sur-Alzette	R	R	S
Esch-sur-Alzette	R	R	S
Esch-sur-Alzette	R	R	S
Grevenmacher	R	R	S
Luxembourg	R	R	S
Remich	R	R	S
Remich	R	R	S
Remich	R	R	S
Remich	R	R	S
Remich	R	R	S
Remich	R	R	S
Remich	S	R	S

The scale of rating was the following: S, as less than 5% survival of plants at label dose 1x; MS, as 5% to 20% survival of plants at label dose 1x; MR, as 20% or more survival of plants at label dose 1x; R, as 20% or more survival of plants at label dose 1x & as 10% or more survival of plants at dose x3.

As black grass control strategies in winter oilseed rape often rely on winter applications of HRAC K1 group active substance propyzamide, with virtually no resistance reported so far, this represents a safe and precise solution. Another powerful solution against black grass in winter oilseed rape, the HRAC K2 active substance carbetamide, is currently not approved for sale in Luxembourg.

Acknowledgements

We thank Alain Majerus, Gilles Parisot and Doriane Dam for technical assistance, the Ministry of Agriculture, Viticulture and Rural Development for funding the projects ANGEL, DIGITAL PILOT FARMS, SENTINELLE and the Ministry of Agriculture, Viticulture and Rural Development, the Ministry of the Environment, Climate and Sustainable Development and the Ministry of Higher Education and Research for financially supporting the project EFFO.

References

EICKERMANN, M., M. FIEDLER, F.K. RONELLENFITSCH, T. GALLÉ, A. MAJERUS, J. JUNK, 2016: Reducing pesticides in oilseed rape production – A multisite long-term field experiment in Luxembourg. IOBC/wprs Bulletin **116**, 13-14.

KARIER, P., G. KRAUS, I. KOBLER, 2017: Metazachlor traces in the main drinking water reservoir in Luxembourg: a scientific and political discussion. Environmental Sciences Europe **29**, 25.

MOSS, S., 2017: Black-grass (*Alopecurus myosuroides*): Why has this weed become such a problem in western europe and what are the solutions? Outlooks on Pest Management **28**, 207-212.

OERKE, E.-C., 2006: Crop losses to pests. Journal of Agricultural Science **144**, 31-43.

PANOZZO, S., L. SCARABEL, A. COLLAVO, M. SATTIN, 2015: Protocols for robust herbicide resistance testing in different weed species. J. Vis. Exp. **101**, e52923.

STATEC, 2017: https://agriculture.public.lu/dam-assets/statistiques/produits-phyto/matiere-active-pesticides-2013-2017.xlsx

STATEC, 2018: https://statistiques.public.lu/stat/TableViewer/tableView.aspx?ReportId=13352&IF_Language=fra&MainTheme=4&FldrName=2&RFPath=7274