

Control of Umbelliferae in Grassland and Pasture, a new herbicide containing ArylexTM active

Bekämpfung von Umbelliferae in Wiesen und Weiden, ein neues Herbizid mit dem Wirkstoff ArylexTM active

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Abstract

Anthriscus sylvestris is a perennial or biennial herbaceous plant in permanent grassland and pasture. With its half rosette it is able to displace valuable forage grasses and has only a medium feed value. At present, no effective and long-lasting solutions with selective acting herbicides is available against it and other hard-to-control weeds of the Umbelliferae family.

ArylexTM active (halauxifen-methyl) is a new active ingredient in the subgroup of aryl picolinates belonging to synthetic auxins. Herbicides containing this active ingredient have been marketed in Germany since 2018 for weed control in cereals.

For the use in grassland and pasture GF-3635 is now under development by Corteva Agriscience in Germany and other European countries. It is a premix of Arylex, fluroxypyr and triclopyr and contains at the 1.5 L/ha maximum use rate 10 g/ha Arylex, 300 g/ha Fluroxypyr and 300 g/ha triclopyr. GF-3635 is thus a further development of the Product Starane Ranger® available since 2005, Ranger® since 2012 respectively, with equal amounts of fluroxypyr and triclopyr per hectare. It can be safely applied during the whole vegetation period, does not harm valuable grass species and has no negative impact on yield quantity and Forage quality. GF-3635 controls *A. sylvestris*, *Heracleum sphondylium*, *Plantago lanceolata*, *Ranunculus acris*, *Ranunculus repens*, *Rumex crispus*, *Rumex obtusifolius*, *Taraxacum officinale* and *Urtica dioica*.

Keywords: *Anthriscus sylvestris*, *Heracleum sphondylium*, *Ranunculus* spp. *Rumex* spp. *Taraxacum officinale*, *Urtica dioica*

Zusammenfassung

Anthriscus sylvestris ist eine mehr- oder zweijährige, krautige Pflanze im Dauergrünland. Mit seiner halben Rosette verdrängt es wertvolle Futtergräser und hat nur einen mittleren Futterwert. Gegen dieses und andere schwer bekämpfbare Unkräuter aus der Familie der Doldenblütler gibt es derzeit keine wirksamen und nachhaltigen Lösungen mit selektiv wirkenden Herbiziden.

ArylexTM active (Halauxifen-Methyl) ist ein neuer Wirkstoff aus der zu den synthetischen Auxinen gehörenden Untergruppe der Arylpicolinate. Herbizide mit diesem Wirkstoff werden in Deutschland seit 2018 zur Unkrautbekämpfung in Getreide vermarktet.

Für den Einsatz in Wiesen und Weiden wird GF-3635 derzeit von Corteva Agriscience in Deutschland und anderen europäischen Ländern entwickelt. Es ist eine Mischung aus Arylex, Fluroxypyr und Triclopyr und enthält bei einer maximalen Aufwandmenge von 1,5 l/ha 10 g/ha Arylex, 300 g/ha Fluroxypyr und 300 g/ha Triclopyr. GF-3635 ist eine Weiterentwicklung des seit 2005 verfügbaren Produktes Starane Ranger®, bzw. Ranger® ab 2012 mit gleichen Mengen an Fluroxypyr und Triclopyr pro Hektar. Es kann sicher während der gesamten Vegetationsperiode angewendet werden, schädigt keine wertvollen Grasarten und hat keinen negativen Einfluss auf den Trockenmasseertrag oder die Futterqualität. GF-3635 bekämpft *A. sylvestris*, *Heracleum sphondylium*, *Plantago lanceolata*, *Ranunculus acris*, *Ranunculus repens*, *Rumex crispus*, *Rumex obtusifolius*, *Taraxacum officinale* und *Urtica dioica*.

Stichwörter: *Anthriscus sylvestris*, *Heracleum sphondylium*, *Ranunculus* spp. *Rumex* spp., *Taraxacum officinale*, *Urtica dioica*

Introduction

An intensive use management on permanent pasture enables the production of coarse forage for milk production with comparable feed qualities, also in competition with feed production from silage maize (TAUBE, 2009). Prerequisite for this are grass swards with energy and protein-rich plants. In addition to a need-based fertilization and use regimes, selective weed control and measures for

reseeding grass for closing gaps are permanently required. While there are effective solutions available against certain dominant weeds, they are lacking in other species. Many Umbelliferous weeds are not or only partially controlled with selectively acting herbicides. Especially against *Anthriscus sylvestris* no effective and long-lasting solution is available (BÄR et al., 2017; BENKER et al., 2017)

A. sylvestris is a perennial or biennial herbaceous plant with a root turnip. With its half rosette it is able to displace valuable forage grasses and has only a medium feed value (KLAPP, 1971). The species is especially promoted by the application of slurry or manure.

New herbicidal active ingredients for the use in grassland and pasture are very rare. More than 12 years after the introduction of Aminopyralid, Corteva Agriscience is now developing Arylex™ active, a new active ingredient for this indication. Arylex (halauxifen-methyl) is an active ingredient in the subgroup of aryl picolinates belonging to synthetic auxins. Herbicides containing this active ingredient have been marketed in Germany since 2018 for weed control in cereals (Zypar, Pixxaro EC). GF-3635 contains Arylex, fluroxypyr and triclopyr and is currently under development in Benelux, France, Germany, Ireland and the United Kingdom.

Materials and methods

First preliminary field testing of Arylex in Grassland and Pasture in Europe started 2013 whereas the development of GF-3635 began 2016.

Field trials have been carried out in Belgium, France, Germany, Ireland, Netherland and the United Kingdom by using small plot sprayers. These trials have been set up during the whole vegetation period between March and October, generally in established grassland and pasture with three to four replicates at a plot size between 12 and 25m².

The effectiveness in control of target weeds has been measured in a percentage scale relative to the untreated control. The first evaluation in efficacy and selectivity was carried out in the standing sward 2-3 weeks after the application. As the sites have been cut regularly, further investigations were no longer possible in relation to the initial stock. Therefore, the % coverage or the number of weed plants have been worked out for each plot individually at time of applications and on each rating time to allow to calculate the effectiveness by using the Henderson-Tilton-Transformation (HENDERSON and TILTON, 1955). Trials that were made in the spring to early summer were evaluated next to the assessment after the application in the regrowth after the first cut and at the end of the growing season. In trials which were carried out in autumn, the most relevant assessment has been done in the following spring.

Crop selectivity and yield was evaluated in pure *Lolium sp.* swards without weed infestation at target dose (1x) and double dose rate (2x).

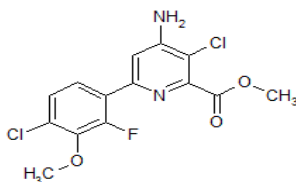
Characteristics of Arylex (halauxifen-methyl)

Chemical and physical properties

Chemical name methyl 4-amino-3-chloro-6-(4-chloro-2-fluoro-3-methoxyphenyl) pyridine-2-carboxylate

Chemistry Arylpicolinate

Chemical structure



Empirical formula $C_{14}H_{11}Cl_2FN_2O_3$

Molecular weight 345.17 g/mol

Melting point 145.5 °C

$\log P_{ow}$ pH7 = 3.76

Aqueous photostability 0.129 hours at pH7

Solubility (mg/L at 20°C) Water at pH5 (1.66), pH7 (1.67), pH9 (1.69)

Mammalian toxicology

Acute oral LD50 > 5000 mg/kg (rat)

Acute dermal LD50 > 5000 mg/kg (rat)

Eye irritation Mild irritation, resolved in 24 hours (rabbit)

Dermal irritation Mild irritation, resolved in 24 hours (rabbit)

Adverse effects not genotoxic, not immunotoxic, not neurotoxic, not carcinogenic, not a reproductive toxicant

Environmental toxicology

Bird acute oral LD50 > 2250 mg/kg bw

Rainbow trout LC50 > 2.01 mg/L

Daphnia magna EC50 > 2.12 mg/L

Honey bee (oral) LD50 > 108 µg/bee

Earthworm (acute) LC50 > 1000 mg/kg soil

Green alga EC50 > 0.245 mg/L

Arylex™ active is practically non-toxic to terrestrial species, it exhibits moderate toxicity to fish and aquatic invertebrates and moderate to high toxicity to freshwater and marine algae.

Characteristics of GF-3635

Ingredients: halauxifen-methyl (6.7 g AE/L)
+ fluroxypyr-meptyl (200 g AE/L)
+ triclopyr-butotyl (200 g AE/L)

Formulation: Emulsifiable Concentrate (EC)

Recommended dose rate: 1.5 L/ha

Application timing: March-October

Mode of action: Synthetic Auxin HRAC Group O

Results

Range finding tests

Range finding tests of Arylex™ active for the use in established pasture initially have been started in 2013.

A total of three field trials were conducted in Germany to particularly assess the efficacy of Arylex against *A. sylvestris*. In that trial set Arylex was used at rates between 2.5 g AE/ha and 15.0 g AE/ha each in tank with methylated seed oil adjuvant at 0.5 L/ha.

The evaluations were carried out in the regrowth after the first cut in a period between 44 days and 66 days after the application in April and May respectively. To validate the results, the raw data were subjected to a regression analysis (Fig. 1). This showed a clear dose-response relationship. Based on this regression equation, efficiencies of Arylex against *A. sylvestris* were calculated for the application rates of 2.5, 5.0 and 7.5 g AE/ha respectively at 73.7%, 85.9% and 93.0% whereas the use rate of 10.0 g AE/ha would have an effect of 98.0% with a prediction interval between 94.5% and 100%.

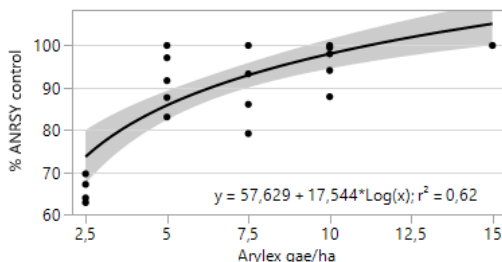


Fig. 1 Regression analysis of the effect of Arylex (plus Adjuvant) against *A. sylvestris* achieved in the regrowth after cut at 6-9 weeks after application, n=3 trials.

Abb. 1 Regressionsanalyse der Wirkung von Arylex (plus Netzmittel) auf *A. sylvestris*, Bonituren im Neuaufwuchs nach Schnitt, 6-9 Wochen nach der Behandlung, n=3 Versuche.

Tank mix studies

During the development of Arylex in the grasslands, it showed both its strengths and its gaps in the control of important broad leave weeds in established grassland and pasture. A pasture herbicide market survey carried out in Germany (KLEFFMAN, 2002) clearly showed the large economic importance of *Rumex obtusifolius*, *Taraxacum officinale*, *Ranunculus* spp. and *Urtica dioica* as well as of Umbelliferous weeds like *A. sylvestris* or *Heracleum sphondylium* and *Plantago lanceolata*.

Arylex has only a slight effect on *R. obtusifolius* and *U. dioica*, on the other hand, market-established grassland herbicides based on fluroxypyr and triclopyr have no or only minor effects on many umbelliferous weeds. It was therefore obvious to combine the individual strengths of these active ingredients in one product. For this purpose, a total of 21 field studies were carried out in Germany, France, Ireland and the United Kingdom during 2013 and 2014. The trials included Arylex at 10 g/ha applied alone, fluroxypyr and triclopyr both at 300 g/ha applied alone and the resulting tank mix of both variants. Table 1 is showing the results of these tankmix studies. The assessments have been done in the regrowth after the first cut following a spring application in April or May. Arylex™ active applied alone has demonstrated good (80-90%) to excellent control (90-100%) of *H. sphondylium*, *A. sylvestris* and *Ranunculus repens*, significantly superior to the mixture of Fluroxypyr and Triclopyr. *Ranunculus acris* has been excellently controlled as well, even though there was no statistical difference to the performance of fluroxypyr+triclopyr which tended to be weaker. The mixture fluroxypyr+triclopyr has proven its capability in control of *R. obtusifolius* which was superior to Arylex. The 3-way mixture of Arylex+fluroxypyr+triclopyr on corresponding rates was always equal or slightly better than the mixing partners applied alone. The efficacy of both tank mix components against *T. officinalis* was comparable but reached only a level of about 70% compared to the untreated control. Although no difference could be detected from a statistical point of view, the effect of the 3-way combination was with almost 90% higher than the single effects of the two tank mix components.

Tab. 1 Comparison of Arylex at 10 g/ha + adjuvant, fluroxypyr+triclopyr at 300 g/ha each and the corresponding tank mix, spring 2013 and 2014, achieved in the regrowth after cut, 5-12 weeks after application.

Tab. 1 Vergleich von Arylex 10 g/ha + Netzmittel, Fluroxypyr+Triclopyr mit je 300 g/ha und der entsprechenden Tankmischung, Frühjahr 2013 und 2014, Bonituren im Neuaufwuchs nach Schnitt, 5-12 Wochen nach der Behandlung.

Weed	Trials	Arylex 10 g/ha+adjuvant		Fluroxypyr+Triclopyr 300 + 300 g/ha		Arylex+Fluro.+Triclo. 10 + 300 + 300 g/ha	
		Mean	(Min - Max)	Mean	(Min - Max)	Mean	(Min - Max)
<i>Anthriscus sylvestris</i>	n=3	93.9 a	(87.5 - 97.2)	32.8 b	(22.4 - 49.8)	99.4 a	(99.3 - 99.5)
<i>Heracl. sphondylium</i>	n=4	85.0 a	(72.3 - 90.8)	58.0 b	(39.5 - 86.8)	86.3 a	(81.5 - 92)
<i>Ranunculus acris</i>	n=4	90.6	(79.6 - 99.5)	58.5	(25 - 93.3)	97.0	(96 - 98)
<i>Ranunculus repens</i>	n=5	92.2 a	(85 - 98)	72.5 b	(56.7 - 90.8)	94.3 a	(91.3 - 97.3)
<i>Rumex obtusifolius</i>	n=9	38.3 b	(2.5 - 63.3)	84.2 a	(73.3 - 96.9)	85.9 a	(80.5 - 96.6)
<i>Taraxacum officinale</i>	n=4	71.6	(27 - 90)	69.1	(41 - 84.8)	89.6	(70.5 - 100)

Means followed by the same letter do not significantly differ (P=0.05, Tukey-Kramer HSD)

Broadleaf weed spectrum

To demonstrate the performance of GF-3635 two market standards have been chosen. Ranger® (Registration No. 007003-00) was used for most of the trials. MCPA was used as reference for the trials where *R. acris* or *R. repens* was the target weed because Ranger® has only limited effectiveness against both weeds. A total of 66 trials have been carried out in Belgium, France, Germany, Ireland and the United Kingdom between 2016 and 2018. Applications have been done either in spring to early summer (March-June) or in autumn (September-October). Table 2 shows the long-term efficacy of GF-3635 and the standards. Results were obtained either at the end of the growing period in autumn when the treatment was made in the spring (3-8 months after application) or in the following spring in case of autumn treatments (5-8 months after application).

GF-3635 significantly outperformed Ranger in efficacy against *A. sylvestris*, *H. sphondylium* and *Plantago lanceolata*. The effect on *R. acris* was slightly lower than that of MCPA, while GF-3635 had a slightly better effect on *R. repens*. From a statistical point of view, however, no differences were detected to the MCPA, which is characterized by its general good effect against these two weed species. There were also no significant differences in the effect of GF-3635 and Ranger against *R. obtusifolius* and *Rumex crispus*. The performance results essentially from the effect of fluroxypyr and triclopyr. Nevertheless, the GF-3635 achieves marginally better efficacy mainly by reducing the variability of the individual trial results. The same tendency is clearly evident with respect to the control of *T. officinale*.

Tab. 2 Long-term performance of GF-3635 compared to relevant market standards, 2016-18, spring and autumn applied, assessed 3-8 months after application at the end of the growing season or in the following spring.

Tab. 2 Langzeitwirkung von GF-3635 im Vergleich zu relevanten Marktstandards, 2016-18, Frühjahrs- u. Herbstbehandlungen, Bonituren 3-8 Monate nach der Behandlung zum Ende der Wachstumsperiode oder im folgenden Frühjahr.

Weed	Trials	GF-3635 1.5 L/ha		Ranger® 2 L/ha		MCPA 500 2 L/ha	
		Mean	(Min-Max)	Mean	(Min-Max)	Mean	(Min-Max)
<i>Anthriscus sylvestris</i>	n=10	95.8 a	(88.8-100)	49.6 b	(0-96.3)		
<i>Heracl. sphondylium</i>	n=11	95.9 a	(78.4-100)	77.6 b	(49.8-97.5)		
<i>Leontodon autumnalis</i>	n=1	100	(100-100)	97.5	(97.5-97.5)		
<i>Plantago lanceolata</i>	n=3	93.9 a	(86.8-100)	52.2 b	(36.8-75)		
<i>Ranunculus acris</i>	n=6	91.2	(78.6-100)			95.7	(87.3-100)
<i>Ranunculus repens</i>	n=8	90.8	(80-100)			82.5	(60-99.8)
<i>Rumex crispus</i>	n=2	83.6	(79.7-87.5)	78.0	(72.5-83.4)		
<i>Rumex obtusifolius</i>	n=14	94.1	(82-100)	91.0	(53.5-100)		
<i>Taraxacum officinale</i>	n=13	93.6	(77.8-100)	86.1	(56.6-100)		
<i>Urtica dioica</i>	n=6	89.9	(79.3-99.5)	89.9	(75-99.5)		

Means followed by the same letter do not significantly differ (P=0.05, Tukey-Kramer HSD)

Crop safety and yield impact

GF-3635 has shown good grass crop selectivity but harms legumes. This is essentially based on the mode of action and the well-known clover damage of fluroxypyr and triclopyr.

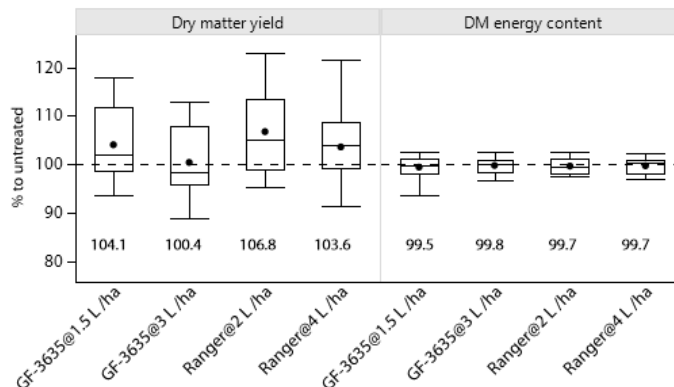


Fig. 2 Relative dry matter yield and forage energy content after application of GF-3635 and standard at 1x and 2x-rate in weed free *Lolium* sp. sites; n=13 trials.

Abb. 2 Relativer Trockensubstanzertrag und Futterenergiegehalt nach Behandlung mit GF-3635 und Standard mit 1x und 2x Aufwandmenge in unkrautfreien *Lolium* sp. Beständen; n = 13 Versuche.

Between 2016 and 2018 a total of 13 trials were conducted to demonstrate the grass selectivity and yield impact in weed free *Lolium perenne* and *Lolium multiflorum* sites. Applications have been done from April to June either in the first growth or in the regrowth after a cut by using the 1x and 2x rate of GF-3635 and the commercial Standard Ranger. Depending on the time of treatment and the differences in yield expectations the absolute dry matter yield differed in a range from 1.2 to 7.8 tons per hectare with a mean at 4.6 tons/ha. To eliminate this high variability from one site to another the dry matter yield relative to untreated has been calculated. The same has been done for the quality parameters where different country specific methods have been used to determine these quality parameters. GF-3635 with the requested and the double dose rate, as well as Ranger at 1x and 2x dose rate, showed no adverse effect on dry matter yield as a percentage of the

untreated. As shown in Figure 2 the yields were at least on the level of the untreated plot, sometimes slightly above it. Likewise, no negative deviations from the percentage of energy content in the dry matter were found.

Discussion

The new herbicide GF-3635 developed by Dow Agrosciences, now Corteva Agriscience, contains the active ingredients Arylex™ active (halauxifen-methyl), fluroxypyr and triclopyr. Arylex belongs to the aryl picolinates, a subgroup of the synthetic auxins. GF-3635 has been specially designed to fulfill gaps of the current commercial standard Ranger® against key target weeds in established grassland and pasture. First preliminary field testing's of Arylex at 10 g AE/ha have shown the strong activity against umbelliferous weeds such as *A. sylvestris* and *H. sphondylium* but also against buttercup species. Particular importance is attached to *A. sylvestris*, as this species cannot be effectively controlled by selective acting herbicides so far (BÄR et al., 2017; BENKER et al., 2017).

A. sylvestris is a perennial or biennial herbaceous plant with a root turnip. The species is especially promoted by the application of slurry or manure. With its half rosette it is able to displace valuable forage grasses and has only a medium feed value (KLAPP, 1971).

Selective acting herbicides in grassland and pasture should show not only a quick initial efficacy to rapidly remove unwanted and, in some cases, potentially poisonous herbs and create space for reseeding of grasses, but also a long-lasting effect for the year of treatment and beyond. In this sense, GF-3635 has demonstrated outstanding efficacy against *A. sylvestris* (95.8%), providing for the first time a product for the selective and sustainable control of this weed. The herbicidal effect against *H. sphondylium* and *P. lanceolata* are also significantly improved over the standard. One of the gaps that the standard Ranger has had so far has been the low performance on buttercups. The new combination with Arylex now achieves over 90% efficacy against *R. acris* and *R. repens* which is comparable to MCPA. Arylex alone has little impact on *Rumex spp.* and *U. dioica*, however, has a remarkable performance against *T. officinale*. This tends to increase the performance against dandelions in combination with fluroxypyr and triclopyr compared to these two active ingredients applied alone. Along with its good selectivity on important grass species, GF-3635 has demonstrated broad spectrum and long-lasting efficacy against a wide range of perennial weeds in established grassland and pasture.

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