Control of ALS resistant volunteer oil seed rape and other dicotyledonous weeds with GF-145, a new cereal herbicide product containing isoxaben and florasulam

Bekämpfung von ALS resistentem Ausfallraps und anderen dikotyledonen Unkräutern mit GF-145, einem neuen Getreideherbizid bestehend aus Isoxaben und Florasulam

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Abstract

GF-145 contains the active ingredients isoxaben (610 g ai/kg) and florasulam (40 g ai/kg) and is formulated as a Wettable Granule (WG). The active ingredients are found in commercial products such as Primus™[2] (florasulam), Starane XL™ (fluroxypyr + florasulam), Ariane C™ (fluroxypyr + florasulam + clopyralid) or Flexidor™ (isoxaben). While florasulam has been widely used in cereal crops in recent years, isoxaben offers a new mode of action (MOA) for use in German cereal herbicides even when considering that Flexidor™ has had regulatory approval in 1988 to 1991. The MOA of isoxaben is inhibition of cellulose synthesis (HRAC class L), while florasulam inhibits Acetolactate Synthase (ALS) and is a representative of the HRAC class B. It is known that florasulam works through uptake by green leaves. Isoxaben is a herbicide with soil activity and with a very low activity when foliar applied, except on some species in the cruciferae family. GF-145 is intended to be applied in the autumn in cereals (wheat, barley, rye, triticale) for the control of ALS resistant volunteer oil seed rape and annual dicotyledonous weeds including *Matricaria* spp., *Stellaria media*, *Papaver rhoeas*, *Capsella bursa-pastoris*, *Myosotis arvensis*, *Lamium* spp., *Galium aparine, Veronica* spp. and others when applied at early post-emergence from BBCH 10 to 13 of the crop. The use rate in winter cereals is 95 g product/ha (58 g ai/ha isoxaben plus 3.75 g ai/ha florasulam). Field trials conducted in previous years confirmed excellent selectivity in all cereal crops and efficacy trials initiated in autumn 2012 show that GF-145 provides excellent and superior control to ALS resistant oil seed rape that was better than straight florasulam and other ALS active ingredients. GF-145 adds a new MOA to the cereal herbicide portfolio and controls volunteer oil seed rape, cruciferous weeds and broad-leaved weeds and is more robust than florasulam based products that do not contain isoxaben.

Keywords: ALS resistant oil seed rape, dicotyledonous weeds, florasulam, isoxaben, volunteer rape, winter cereals

Zusammenfassung

GF-145 enthält die Wirkstoffe Isoxaben (610 g AS/kg) und Florasulam (40 g AS/kg) und ist als wasserdispergierbares Granulat (WG) formuliert. Die beiden Wirkstoffe sind bestens bekannt aus Produkten wie Primus™ (Florasulam), Starane XL™ (Florasulam + Fluroxypyr), Ariane C™ (Florasulam + Fluroxypyr + Clopyralid) oder Flexidor™ (Isoxaben). Während Florasulam in den vergangenen Jahren im Getreide häufig eingesetzt wurde, hat Isoxaben einen neuen Wirkungsmechanismus (MOA) im Getreide, auch wenn Isoxaben im Zeitraum 1988-1991 hier eine Zulassung hatte. Isoxaben wirkt dabei durch eine Hemmung der Zellulosebildung (HRAC Klasse L), während Florasulam als Vertreter der HRAC Klasse B die Acetolactatesynthase behindert. Die Aufnahme von Florasulam in die Pflanze erfolgt über die Blätter. Im Gegensatz dazu wird Isoxaben von den Wurzeln über den Boden aufgenommen und besitzt nahezu keine Blattaktivität, abgesehen bei einigen Arten aus der Familie der Kruziferen. Die Anwendung von GF-145 erfolgt im Herbst im Getreide (Weizen, Gerste, Roggen, Triticale). Es werden ausgezeichnet Ausfallraps (BRSNW) einschließlich ALS-resistentem Ausfallraps, sowie dikotyle Unkräuter wie Kamillearten (*Matricaria* spp.), Vogel-Sternmiere (*Stellaria media*), Klatschmohn (*Papaver rhoeas*), Gemeines Hirtentäschelkraut (*Capsella bursa-pastoris*), Acker-Vergißmeinicht (*Myosotis arvensis*) und Taubnesselarten (*Lamium* spp.) bekämpft, Kletten-Labkraut (*Galium aparine*) und Ehrenpreisarten (*Veronica* spp.) werden mit etwas geringeren aber ebenfalls guten Wirkungsgraden bekämpft. Die Applikation erfolgt im frühen Nachauflauf (BBCH 10-13) der Kultur mit einer Aufwandmenge von 95 g/ha, wobei 58 g/ha Isoxaben und 3,75 g/ha Florasulam appliziert werden. In den vergangenen Jahren durchgeführte Feldversuche zeigen eine ausgezeichnete Verträglichkeit in allen Getreidearten sowie eine deutliche Überlegenheit von GF-145 bei der Bekämpfung von ALS-resistentem

[2] ™Trademark of the Dow Chemical Company ("Dow") or an affiliated company of Dow

Ausfallraps gegenüber Florasulam und anderen ALS-Wirkstoffen. Das neue Herbizid GF-145 stellt mit dem Wirkstoff Isoxaben einen neuen MOA für die Unkrautbekämpfung im Herbst bereit und bietet damit neue Lösungsmöglichkeiten für die Bekämpfung von Ausfallraps und anderen kruziferen Unkräutern sowie vielen weiteren dikotylen Unkräutern.

Stichwörter: ALS-resistenter Ausfallraps, dikotyle Unkräuter, Florasulam, Isoxaben, Wintergetreide

Introduction

GF-145 is a new cereal herbicide which contains isoxaben (610 g ai/kg) and florasulam (40 g ai/kg). Florasulam is well known from Starane XL™ (fluroxypyr + florasulam, 100 + 2.5 g/L, SE) and Primus™ (florasulam, 50 g/L, SC). Florasulam controls *Galium aparine*, *Matricaria* sp., *Polygonum convolvulus*, *Papaver rhoes* and cruciferous weeds including volunteer rape (SCHLOTTER *et al.*, 1998) and has also regulatory approval for uses in autumn (BECKER *et al.*, 2004). Isoxaben has regulatory approval in forestry, ornamentals and orchards with a maximum use rate of 1.0 L/ha (500 g ai/ha isoxaben). Historically, isoxaben was approved in Germany for uses in cereals in 1988 to 1991 at maximum use rate of 100 g ai/ha isoxaben to control *Brassica napus*, *Veronica persica*, *P. rhoeas* and *Lamium* spp.. Isoxaben inhibits cellulose synthesis and florasulam is an ALS inhibitor that provides superior control of GALAP and other weeds in cold conditions (BECKER *et al.*, 2000; BECKER *et al.*, 2002). In recent years, ALS resistant *Matricaria* spp. (MATSS) has been occasionally observed (SCHLEICH-SAIDFAR *et al.*, 2011). Furthermore, the introduction of the ALS resistant oil seed rape Clearfield®[3] has created the need for robust herbicides to manage occurrence and spread of volunteer oil seed rape (KRATO and PETERSEN, 2012 b) to reduce the competitive effect of volunteer oil seed rape on the yield of the following crop (KRATO and PETERSEN, 2012 a). GF-145 provides residual control through isoxaben on ALS resistant cruciferous weeds combined with the well known efficacy of florasulam (i.e. GALAP control under cold conditions).

Materials and methods

Development trials with GF-145 were conducted from 2001 to 2012 in Germany, France and the UK by Dow AgroSciences internal field research and development personnel or trials were carried out by contract organizations in accordance with GEP. Most trials were designed as randomized complete block with 4 replicates, plot size was 12 to 30 m^2 and weed control of GF-145 and commercial standards were assessed 2 and 4 weeks after application and in following spring. Phytotoxicity to cereal crops was assessed 1 week after application and continued as long as symptoms were visible. The weed control was rated visually as an overall score of the percentage control or phytotoxicity relative to the non-treated check. Crop selectivity and yield was evaluated in trials without weed competition. In crop selectivity trials, GF-145 was applied at target dose (95 g FP/ha) and double dose rate (190 g FP/ha). Trials with Clearfield® oil seed rape drilled into cereal crops were conducted in 2012. The occurrence of the characteristic resistance genes (ALS I with position Ser-653, ALS III with position Trp-574) in the drilled oil seed rape seeds was confirmed by IdentXX GmbH.

Characteristics of GF-145

Active ingredients:	florasulam (40 g ai/kg) + isoxaben (610 g ai/kg)
Formulation:	Water Dispersible Granules (WG)
Target crops:	Winter cereals (soft wheat, barley, rye, triticale)
Target dose rate:	95 g FP/ha
Application timing:	BBCH 10-13 in autumn
Mode of action:	Acetolactate synthase inhibitor (ALS, HRAC B) + cellulose synthesis inhibitor (HRAC L)
Symbol:	N
Bee toxicity:	No

[3] ®Clearfield is a trademark of BASF Crop Protection

Results

Weed spectrum

GF-145 was tested in winter cereals at application timing BBCH 10 to 13. GF-145 performed in winter cereals at very high levels (>95% efficacy) on cruciferous weeds including volunteer rape (*B. napus*, *Capsella bursa-pastoris*, *Descurainia sophia)* and *P. rhoeas*, *Stellaria media* and *L. purpureum*. *Veronica* sp. and *Galium aparine* were moderately susceptible but sufficiently controlled while *Viola arvensis* was not controlled (Tab. 1).

Tab. 1 Weed spectrum of GF-145 (95 g/ha) when applied at BBCH 10 to 13 in winter cereals in the autumn. Figures in brackets indicate number of trials.

Tab. 1 *Unkrautspektrum und Wirkung von GF-145 (95 g/ha) bei Anwendung im Stadium BBCH 10 bis 13 in Wintergetreide im Herbst. Anzahl der Versuche in Klammern.*

Weed species	Weed code	Efficacy of GF-145 at 95 g/ha
Brassica napus subsp. napus	BRSNW	99 (6)
Capsella bursa-pastoris	CAPBP	100 (2)
Descurainia sophia	DESSO	100 (2)
Galium aparine	GALAP	95 (2)
Lamium purpureum	LAMPU	100 (2)
Matricaria chamomilla	MATCH	100 (4)
Myosotis arvensis	MYOAR	99 (3)
Papaver rhoeas	PAPRH	96 (13)
Stellaria media	STEME	99 (4)
Veronica arvensis	VERAR	100 (1)
Veronica hederifolia	VERHE	83 (3)
Veronica persica	VERPE	91 (7)
Viola arvensis	VIOAR	(15)

Efficacy on ALS resistant oil seed rape (Clearfield®)

GF-145 was applied at early post emergence (BBCH 10-11) of the crop to the oil seed rape. GF-145 provided excellent efficacy (90% control) 3 to 5 weeks after application (WAA) in autumn 2012 that was superior to the standards flupyrsulfuron methyl (34%) and Primus (63%). Further assessments were done the following year. At final assessment (approximately 27 weeks after application) GF-145 provided excellent control of Clearfield® rape (99%) that was superior to flupyrsulfuron (57%) and Primus (79%). The final control assessments may not reflect valid differences among treatments because extended ambient temperatures below 0°C that occurred in April 2013 caused high oil seed rape mortality. The assessments taken 3 to 5 WAA provide the most reliable efficacy comparisons between GF-145 and the commercial standards.

Tab. 2 Efficacy of GF-145 at 95 g/ha compared to flupyrsulfuron and Primus™ on ALS resistant Clearfield® oil seed rape. Average of 6 trials.

***Tab. 2** Wirkung von GF-145 (95 g/ha) im Vergleich zu Flupyrsulfuron und Primus™ auf ALS-resistenten Clearfield®-Raps. Mittelwert von 6 Feldversuchen.*

Weed species	WAA*	GF-145 at 95 g/ha	flupyrsulfuron methyl at 10 g ai/ha	Primus at 75 mL/ha
ALS res. BRSNW	3 to 5	90	34	62
ALS res. BRSNW	>27	99	57	79

*WAA=Assessment in weeks after application

Crop selectivity and yield response

GF-145 provided excellent winter cereals selectivity when autumn-applied from BBCH 10 to BBCH 13. Phytotoxicity (% visual) was evaluated in 10 trials with wheat and barley treated with single (95 g FP/ha) and double use rates (190 g FP/ha). Crop phytotoxicity symptoms > 5% were not seen in any trial at 95 g/ha and a maximum of 10% injury (chlorosis) was seen in one winter wheat trial at 190 g FP/ha. Injuries - if any - were transient and did not impact crop yield statistically significant as demonstrated (Tab. 3).

Tab. 3 Yield response (in T/ha and relative to the untreated check) of GF-145 at single (95 g FP/ha) and double (190 g FP/ha) use rates when applied to winter cereals at BBCH 10 to 13 in weed free situations (n=number of trials).

***Tab. 3** Ertragseinfluss (absolut und relativ zur unbehandelten Kontrolle) von GF-145 mit einfacher (95 g/ha) und doppelter (190 g/ha) Aufwandmenge in Wintergetreide zu BBCH 10 bis 13 unter unkrautfreien Bedingungen (n=Anzahl der Versuche).*

Crop		TRZAW			HORVW		
Evaluation type		T/ha	%	n	T/ha	%	n
Treatment	Rate (g FP/ha)						
GF-145	95	8,3	101,1	6	6,0	98,7	4
GF-145	190	8,2	99,8	6	6,1	100,9	4
untreated		8,3	100,0	6	6,1	100,0	4

Impact on following crops

The impact on following crops was assessed with the single and double dose rates. Potential succeeding crops planted were winter oil seed rape, winter wheat, field beans and alfalfa the year after application of GF-145 (approximately 10 to 12 month later) and crop planted the following spring (15 to 18 month later) were maize, soybeans, spring oil seed rape, sunflower, field peas and sugar beet. Alfalfa and winter oilseed rape were drilled after minimum soil cultivation while the other crops were drilled after ploughing. No phytotoxicity symptoms were observed in the following crops. However, it is recommended to plough before sowing oil seed rape.

Discussion

GF-145 is a new herbicide containing the active ingredients florasulam and isoxaben. The combination of active substances in GF-145 expands the spectrum of weed species being controlled, including weeds resistant to ALS herbicides compared to florasulam applied alone. The soil residuality of isoxaben enables the control of late emerged weeds not present at application, such as *C. bursa-pastoris* or *L. purpureum*. Furthermore, the benzamide isoxaben adds a new mode

of action to the cereal herbicide portfolio and it is the only herbicide product in the German herbicide market belonging to HRAC class L. GF-145 controls ALS resistant weeds (such as *Matricaria* spp.) and volunteer Clearfield® oil seed rape. In addition, recent studies have shown that florasulam (belonging to the triazolo-pyrimidines) still controls ALS target site resistant *Matricaria* spp. that is no longer controlled by sulfonylurea herbicides (SCHLEICH-SAIDFAR *et al.*, 2011; ULBER *et al.,* 2012).

In autumn, early post-emergence applied GF-145 provides excellent control of cruciferous weeds (*Brassica* spp. and others), *P. rhoeas, S. media, Lamium* spp. and good control of *G. aparine* and *Veronica* spp. The weed spectrum and the early application timing turns GF-145 to an ideal tank-mix partner for early applied graminicides to further broaden weed control spectrum.

Efficacy gaps are likely going to evolve due to the introduction of ALS resistant oil seed rape, such as Clearfield® varieties. It was shown by KRATO and PETERSEN (2012 b) that florasulam provides in contrast to sulfonylureas good level of control on ALS resistant volunteer rape. Due to its excellent efficacy on oil seed rape isoxaben adds ideally florasulam in preventing spread and negative yield impact on the cereal crop as reported by KRATO and PETERSEN (2012 a) for competitive interaction between cereal crop and volunteer oil seed rape plants.

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