ADVANCES IN SUNFLOWER WEED CONTROL IN THE USA

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Abstract

Lack of effective broadleaf herbicides registered in sunflower has made weeds the most important pest infesting U.S. sunflower production. Trifluralin and ethalfluralin were applied to most sunflower land, which control only a few of the weeds infesting sunflower, and require soil incorporation which limits no-till or conservation tillage. Since 1999, three weed control technologies have been developed in the U.S. for weed control in sunflower. First, sulfentrazone, a soil-applied herbicide, provides residual control of most small-seeded broadleaf weeds, has excellent sunflower safety, and has few crop rotation restrictions. Second, "Clearfield" sunflower is resistant to imidazolinone herbicides, is non-transgenic, and has significantly contributed to no-till sunflower production. Imazamox, a postemergence, ALS herbicide controls most annual grass and broadleaf weeds infesting sunflower in "Clearfield" sunflower, does not control ALS resistant weeds, has excellent safety to Clearfield sunflower, and has some follow-crop rotation restrictions to non-legume broadleaf crops. Third, tribenuron (Express)-resistant sunflower is resistant only to tribenuron of all sulfonylurea herbicides and all other herbicides of ALS chemistries, and is non-transgenic. Tribenuron, a postemergence, ALS herbicide controls most annual broadleaf weeds and *Circium arvensis*, has excellent tribenuron resistant sunflower safety, and has no follow-crop rotation restrictions. These three weed control systems allow control of most grass and broadleaf weeds in U.S. sunflower production and increase the adoption of no-till sunflower production.

Introduction

Sunflower production in the U.S. averages 1.2 to 1.6 m ha with North Dakota growing approximately half of the total acreage. Sunflower is grown in semiarid environments of the U.S. and is an important rotational crop with small grains. Grower surveys conducted in sunflower show weeds to be the most important pest infesting sunflower and lack of wide-spectrum broadleaf weed control is the greatest production problem in U.S. sunflower production (Lamey, 2001, 2003; Lamey and Zollinger, 1992, 1993a, b, 1996, 1999). Weed competition causes substantial yield loss in sunflower. Competition experiments in sunflower show 20 to 53% less yield than weed-free conditions (Blamey and Zollinger, 1997). In North Dakota, more than 94% of sunflower land is treated with a herbicide (Glogoza and Zollinger, 2002; Zollinger, 1993, 1998). The most used herbicides were trifluralin and ethalfluralin which require soil incorporation after application to control annual grasses and a few small-seeded broadleaf weeds (Lamey, 2001, 2003; Lamey and Zollinger, 1992, 1993a, b, 1996, 1999).

The incorporation requirement of trifluralin and ethalfluralin restricts the practice of no-till and reduced-till systems to minimize loss of soil moisture and erosion and the introduction of

one-pass air drills has resulted in more dependency on herbicides for weed control. Other registered herbicides in the U.S. are postemergence imazamethabenz for wild mustard control and sethoxydim for annual and perennial grass control.

Before 1999, no broad-spectrum, broadleaf herbicide was available for use in sunflower. Farmers used tillage, between-row cultivation, crop rotation, and herbicides to control weeds. Herbicides registered in other crops have been screened for potential use in sunflower but lack of success in finding and registering sunflower herbicides has been due to limited U.S. acreage, limited economic return for basic herbicide manufacturers, and injury from most broadleaf herbicides registered in other crops. Sunflower is a major crop internationally and some broadleaf herbicides are available outside the U.S. Some herbicides are acetochlor, aclonifen, flurochloridone, flurtamone, oxadiargyl, oxadiazon, and oxyfluorfen. Metolachlor was labeled in the U.S. in late 2003.

The major weeds infesting sunflower in the U.S. are: *Seteria* species, *Kochia scoparia, Cirsium arvense* L., *Polygonum convolvulus* L., *Iva xanthifolia* Nutt., *Xanthium strumarium* L., *Amaranthus* species, *Artemisia biennis* Willd.„ *Solanum ptychanthum* Dunal., *Chenopodium album* L., *Salsola kali* L., *Brassica* species, and *Ambrosia artemisiifolia* L. (Zollinger and Ries, 2003). Soil-applied trifluralin and ethalfluralin control some small-seeded weeds like *Setaria* species, *Amaranthus* species, and *Chenopodium album* but do not control large-seeded weed species. Growers use up to four cultivations to control weeds that escape chemical weed control.

Materials and Methods

Field studies evaluating sulfentrazone, imazamox in Clearfield sunflower, tribenuron in tribenuron (Express)-resistant sunflower, and response of sunflower to acetolactate synthase (ALS) herbicides were conducted from 1997 to 2003. Treatments were applied to the center 2 m of 3 by 12.2 m plots with a bicycle-type plot sprayer delivering 80 L/ha at 276 kPa through 8001 flat fan nozzles to V4 to V8 sunflower. The experiments were arranged in a randomized complete block design with four replicates per treatment. Evaluations were taken 14, 28, and 56 days after application.

Results and Discussion

Sulfentrazone. University researchers observed sunflower unaffected by sulfentrazone in field studies conducted in 1997 and 1998. Sulfentrazone, from FMC Corporation, has a protoporphyrinogen oxidase inhibitor mode of action, is a soil-applied herbicide, and was registered on many legume and pulse crops, potato, mint, and sunflower in late 2003. The rate labeled in sunflower is 140 to 280 g/ha but varies with soil texture, organic matter and pH. The higher rates are used on fine-textured soils with organic matter greater than 3%. Soil pH greatly influences solubility in the soil, activity on weed control, and risk of crop injury. Solubility increases 1.5X from pH 6 to 7, but increases 2X from pH 7 to 7.5. Injury to sunflower may occur on knolls in fields where organic matter is low, soil texture is coarse and pH is high. At least 1.5 to 2.5 cm of precipitation is required to activate sulfentrazone. The preferred application timing is preemergence but light incorporation will help activate the herbicide under dry conditions after application.

Sulfentrazone controls most small-seeded broadleaf weeds including *Kochia scoparia, Amaranthus* species, *Artemisia biennis, Solanum* species, *Chenopodium album*, and *Salsola kali*, and provides partial control of *Seteria* species, *Polygonum convolvulus, Iva xanthifolia, Xanthium strumarium, Brassica* species, and *Ambrosia artemisiifolia*. Sulfentrazone provides six to 10 weeks residual control of susceptible broadleaf weed species. Sulfentrazone controls weed biotypes that have become resistant to herbicides of other modes of action. The region of the U.S. where sunflower is grown has *Kochia scoparia* biotypes resistant to acetolactate synthase (ALS), triazine, and growth regulator herbicides, and *Amaranthus* species and *Solanum ptychanthum* biotypes resistant to ALS herbicides. Sulfentrazone controls these weedy biotypes.

Sulfentrazone was available to sunflower growers from 1999 to 2003 prior to federal Section 3 registration in late 2003 through Section 18 exemption registration. This special allowance was approved by showing yield loss from uncontrolled weeds and prevention of the yield loss by sulfentrazone. Sulfentrazone registration on sunflower with the U.S. Environmental Protection Agency (EPA) was a combined effort from several agencies: The North Dakota Department of Agriculture, The National Sunflower Association, Interregional Research Project No 4 (IR-4), and several university researchers.

Sulfentrazone has excellent sunflower safety, has residual control of many broadleaf weeds, has few crop rotation restrictions, and provides a major contribution by allowing growers to grow sunflower and control broadleaf weeds in the moisture conserving, no-till system.

Clearfield Sunflower. Dr. Kassim Al-Khatib, Weed Scientist, Kansas State University, identified an imidazolinone (IMI) resistant wild sunflower in 1996 and collaborated with Dr. Jerry Miller, USDA ARS sunflower geneticist, Fargo, ND to develop imidazolinone-resistant cultivated sunflower from the weedy resistant biotype. Pollen and seed was made available to the private sunflower hybrid seed industry. The basic manufacturer of imidazolinone herbicides, BASF Corporation, supported development and registration efforts in 2000 and subsequently named the technology, "Clearfield." Imazamox was registered for weed control in Clearfield sunflower in late 2003. Clearfield sunflower is not transgenic but was developed through conventional breeding techniques. Imidazolinone resistant sunflower has a single modified ALS gene with semidominant inheritance. Advanced lines have a 2X resistance to imazamox, imazethapyr, and imazapyr. Field research has shown tolerance up to 3X in commercial Clearfield sunflower lines.

Imazamox, from BASF Corporation, is a postemergence, ALS inhibitor mode of action herbicide, and is labeled at 35 g/ha for application to Clearfield sunflower from 2 to 8-leaves. Nonionic surfactant adjuvant is recommended with ammonium fertilizer but oil adjuvants are not restricted. Imazamox controls most weeds infesting sunflower including *Seteria* species, ALS susceptible *Kochia scoparia, Iva xanthfolia, Xanthium strumarium*, ALS susceptible *Amaranthus* species, *Solanum ptychanthum, Chenopodium album, Salsola kali*, and *Brassica* species. Imazamox gives only partial control of *Ambrosia artemisiifolia, Polygonum convolvulus*, and *Artemisia biennis* and no control of *Circium arvensis*.

Imidazolinone herbicides are one of four chemistries in the ALS herbicide mode of action group. Other chemistries are sulfonylureas (chlorsulfuron, metsulfuron, nicosulfuron, tribenuron, thifensulfuron, others), triazolopyrimidines (cloransulam, flumetsulam), and sulfonylaminocarbonyltriazolinones (flucarbazone, propoxycarbazone). Table 1 shows that imidazolinone resistance in sunflower is specific only to the imidazolinone chemistry.

U.S. registration of imazamox on Clearfield sunflower was accomplished by multi-organizational collaboration similar to the way in which sulfentrazone registration and Section 18 exemption registration was approved in 2002 and 2003, and U.S. federal registration was approved in late 2003. Clearfield sunflower represents a major step in advancing weed control in sunflower. Imazamox is the first wide-spectrum, postemergence broadleaf herbicide registered in sunflower. Imazamox controls annual grasses and many pivotal weeds in sunflower, has excellent Clearfield sunflower safety, increases no-till/conservation tillage practices, is non-transgenic, allows flexible crop rotations, and volunteer Clearfield sunflower plants are easily controlled in follow crops.

Table 1. Clearfield sunflower response to ALS herbicides.

Herbicide	Rate	Location 1	Location 2
		% injury	% injury
Tribenuron	1X	33	0
Tribenuron	2X	49	-
Thifensulfuron	1X	99	90
Nicosulfuron	1X	68	53
Metsulfuron	1X	97	-
Foramsulfuron	1X	70	38
Cloransulam	1X	99	71

All treatments were applied with recommended adjuvants.

Express Resistant Sunflower. Express (tribenuron) Resistant Sunflower (ERS) is in development and is projected for registration in 2005. ERS resulted from two different gene sources: 1) DuPont Chemical Company, and 2) collaboration from Dr. Kasim Al-Khatib and Dr. Jerry Miller. Through mutagenesis, DuPont developed ERS in 1992. Selections were purified and tested from 1998 to 2000, and field tested using 1X and 2X rates of tribenuron from 2000 until the present. Dr. Jerry Miller developed ERS from tribenuron-resistant weedy sunflower plants obtained from Dr. Kassim Al-Khatib. ERS sunflower is not transgenic but was developed through conventional breeding techniques. Field research has shown tolerance to 3X in commercial sunflower lines of both gene sources.

Tribenuron, from DuPont Chemical Corporation, is a postemergence herbicide. At 18 g/ha, tribenuron controls most annual broadleaf weeds infesting sunflower including ALS susceptible *Kochia scoparia*, *Iva xanthifolia, Xanthium strumarium*, ALS susceptible *Amaranthus* species, *Solanum ptychanthum, Chenopodium album, Salsola kali*, and *Brassica* species. Tribenuron gives only partial control of *Ambrosia artemisiifolia, Polygonum convolvulus*, and *Artemisia biennis*. With similar broadleaf weed spectrum as imazamox, tribenuron provides full season *Cirsium arvense* control while imazamox gives no control.

Tribururon is a sulfonylurea herbicide in the ALS herbicide mode of action group. Table 2 shows ERS is specific to tribenuron of the sulfonylurea herbicides and other ALS herbicides and herbicides of other ALS chemistries cause death or significant injury.

U.S. registration of tribenuron on ERS was accomplished by multi-organizational collaboration similar to sulfentrazone and imazamox registration. IR-4 field residue trials were conducted in 2001, hybrid lines and seed supply was increased in 2002 and 2003, and U.S. federal registration is projected for 2005. Tribenuron contributes to weed control in sunflower by controlling annual weeds and the perennial weed *Cirsium arvense*

postemergence, has excellent ER sunflower safety, increases no-till/conservation tillage practices, is non-transgenic, and has no follow-crop rotation restrictions.

Table 2. Tribenuron (Express)-resistant sunflower response to ALS herbicides.

Herbicide	Rate	Location 1	Location 2
		% injury	% injury
Metsulfuron	1X	37	57
Nicosulfuron	1X	57	53
Foramsulfuron	1X	87	75
Thifensulfuron	1X	52	-
Thif + Trib	1X	60	-
Imazamox	1X	67	50
Cloransulam	1X	99	99

All treatments were applied with recommended adjuvants.

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