Dry bean response to preemergence flumioxazin

Authors: Adjesiwor, Albert T., Claypool, David A., and Kniss, Andrew R.

Source: Weed Technology, 34(2) : 197-201

Published By: Weed Science Society of America

URL: https://doi.org/10.1017/wet.2019.87

Weed Technology

www.cambridge.org/wet

Research Article

Cite this article: Adjesiwor AT, Claypool DA, Kniss AR (2020) Dry bean response to preemergence flumioxazin. Weed Technol. **34**: 197–201. doi: 10.1017/wet.2019.87

Received: 13 June 2019
Revised: 26 August 2019
Accepted: 30 August 2019
First published online: 7 October 2019

Associate Editor:
Robert Nurse, Agriculture and Agri-Food Canada

Nomenclature:
bentazon; EPTC; ethalfluralin; flumioxazin; imazamox; pendimethalin; trifluralin; dry bean; *Phaseolus vulgaris* L.

Keywords:
Crop injury; crop safety; weed control

Author for correspondence:
Andrew R. Kniss, University of Wyoming, Department 3354, 1000 East University Avenue, Laramie, WY 82071. Email: akniss@uwyo.edu

Dry bean response to preemergence flumioxazin

Albert T. Adjesiwor[1], David A. Claypool[2] and Andrew R. Kniss[3]

[1]Postdoctoral Research Associate, Department of Plant Sciences, University of Wyoming, Laramie, WY, USA; [2]Master Technician, Department of Plant Sciences, University of Wyoming, Laramie, WY, USA and [3]Professor, Department of Plant Sciences, University of Wyoming, Laramie, WY, USA

Abstract

Field studies were conducted from 2009 through 2011 at the Sustainable Agriculture Research and Extension Center near Lingle, Wyoming, to evaluate great northern bean response to PRE flumioxazin mixed with either trifluralin, pendimethalin, or ethalfluralin. Seven treatments were arranged in a randomized complete block with three or four replicates y^{-1}. The soil texture of the study site was loam in 2009 and 2011, and sandy loam in 2010. Soil organic matter ranged from 1.4% to 1.8%. Treatments included flumioxazin plus trifluralin, flumioxazin plus pendimethalin, flumioxazin plus ethalfluralin, ethalfluralin plus EPTC, imazamox plus bentazon (POST), hand-weeded control, and nontreated control. Dry bean density 4 wk after planting differed among herbicide treatments ($P < 0.001$). Treatments that included flumioxazin reduced dry bean density 54% compared with treatments without flumioxazin. Dry bean yield was influenced by dry bean density; on average, yield in flumioxazin-containing herbicide treatments was 30% less than treatments not containing flumioxazin, even though weed control was generally greater in flumioxazin treatments.

Introduction

Dry bean is an important crop in the United States and many other regions of the world. In the United States, dry bean is grown primarily in California, Colorado, Idaho, Michigan, Minnesota, Montana, Nebraska, Washington, and Wyoming. It is a very important crop to the economies of the High Plains of the United States (Wilson and Sbatella 2014). For example, although less than 3% of dry bean produced in the United States comes from Wyoming, the value of dry bean produced in Wyoming exceeded $21 million in 2016 (Brandt and Hussey 2017; USDA-NASS 2019). Dry bean is a crop of short stature and, therefore, a relatively poor competitor for sunlight. Thus, weed control is one of the major concerns in dry bean production (Taziar et al. 2017). It is estimated that in the United States and Canada, potential annual dry bean yield loss from uncontrolled weeds is 71%, which translates to more than $722 million (Soltani et al. 2018a). In addition to yield loss, weeds can reduce dry bean quality, thereby reducing the market value of the crop (Taziar et al. 2017). Weed control, therefore, is a critical management practice in dry bean production (Wilson 2005).

Herbicides remain one of the most important weed management tools in dry bean production. However, there are relatively few herbicides for broadleaved weed control in dry beans compared with other crops (Soltani et al. 2018b). Other effective herbicides need to be identified that are safe to use in dry bean (Soltani et al. 2005).

Flumioxazin (an *N*-phenylphalimide herbicide) is a protoporphyrinogen oxidase inhibitor registered for use in soybean [*Glycine max* (L.) Merr.] and peanuts (*Arachis hypogaea* L.) and has both soil and foliar activity (Shaner 2014). The herbicide controls important broadleaf weeds such as common lambsquarters (*Chenopodium album* L.), black nightshade (*Solanum nigrum* L.), and pigweeds (*Amaranthus* spp.) and can be combined with other preplant herbicides to improve weed control. Some states have issued supplemental labeling that allows flumioxazin to be used for weed suppression in dry bean, although previous reports have suggested unacceptable crop injury under certain environmental conditions. Soltani et al. (2005) showed that different market classes of dry bean respond differently to PRE application of flumioxazin. The authors reported that small-seeded market classes (e.g., white and black beans) were more sensitive to flumioxazin compared with larger-seeded market classes (e.g., cranberry and kidney beans). Thus, medium-seeded market classes such as great northern and pinto beans, which are commonly grown in the region where this study was conducted, might show different sensitivity to flumioxazin. The potential for phytotoxicity of flumioxazin also increases with cool temperatures and high levels of soil moisture after herbicide application (Niekamp et al. 1999; Soltani et al. 2005; Taylor-Lovell et al. 2001).

The suitability of flumioxazin for weed control in dry bean depends not only on the dry bean market class but also soil type, temperature, humidity, and soil moisture. Flumioxazin could provide dry bean growers in Wyoming with an additional weed management option for the control of problematic annual broadleaf weeds, especially hairy nightshade (*S. physalifolium* Rusby) and common lambsquarters. The objective of this study, therefore, was to evaluate dry bean response to soil-applied flumioxazin in Wyoming when mixed with trifluralin, pendimethalin, or ethalfluralin.

Table 1. Soil texture and composition in 2009, 2010, and 2011 at the experimental site, Lingle WY.

Year	Soil texture	Sand	Silt	Clay	OM[a]	pH	CEC
		———	———	%	———	———	mEq 100 g^{-1}
2009	Loam	42	37	21	1.4	7.8	19.6
2010	Sandy loam	56	31	13	1.8	8.0	11.4
2011	Loam	44	35	21	1.8	7.8	21.0

[a]Abbreviation: OM, organic matter.

Table 2. Weed control treatments, herbicide rates, and application timings used in the study.

Treatment	Rate	Timing
	g ai ha^{-1}	
Nontreated control	–	–
Flumioxazin[a] +	560	PRE
trifluralin[b]	54	PPI
Flumioxazin +	54	PRE
pendimethalin[c]	796	
Flumioxazin +	54	PRE
ethalfluralin[d]	840	PRE
EPTC[e] +	2450	PPI
ethalfluralin	840	PPI
Imazamox[fg] +	35	POST
bentazon[h]	560	POST
Hand-weeded control	–	–

[a]Valor SX; Valent, Walnut Creek, CA.
[b]Treflan; Dow AgroSciences, Indianapolis, IN.
[c]Prowl H_2O; BASF, Research Triangle Park, NC.
[d]Sonalan HFP; Gowan Company, Yuma, AZ.
[e]Eptam 7E; Gowan Company.
[f]Raptor; BASF.
[g]Treatment contained urea ammonium nitrate (28-0-0, Agrium, Calgary, Alberta, Canada) at 2.5% vol/vol plus nonionic surfactant (Preference, WinField Solutions, St. Paul, MN) at 0.25% vol/vol.
[h]Basagran; BASF.

Materials and Methods

Field studies were conducted at the Sustainable Agriculture Research and Extension Center near Lingle, Wyoming (42.13°N, 104.39°W), from 2009 through 2011 to evaluate dry bean response to soil-applied flumioxazin mixed with trifluralin, pendimethalin, or ethalfluralin. Soils in the study were Haverson loam (fine-loamy, mixed, superactive, calcareous, mesic Aridic Ustifluvents) and McCook loam (coarse-silty, mixed, superactive, mesic Fluventic Haplustolls) (National Resources Conservation Service 2002). The soil texture of the study site was loam in 2009 and 2011, and sandy loam in 2010 (Table 1). The soil pH was alkaline (7.8 to 8.0) and soil organic matter ranged from 1.4% to 1.8% (Table 1). 'Orion' great northern bean (medium-sized market class), one of the widely grown market classes in Wyoming, was planted in 76-cm rows at a density of 160,000 to 178,000 seeds ha^{-1} on May 29, 2009; June 2, 2010; and June 2, 2011.

There were seven treatments, including a nontreated control and a hand-weeded control. Flumioxazin was mixed with either trifluralin, pendimethalin, or ethalfluralin, which are among commonly used herbicides for weed control in dry bean (Table 2). Ethalfluralin plus EPTC (PPI) and imazamox plus bentazon POST treatments were included as commercial, standard herbicide treatments for comparison with flumioxazin treatments. Inclusion of the hand-weeded control treatment enabled us to evaluate emerged dry bean density and yield in the absence of weeds and crop injury. Similarly, the nontreated control enabled us to evaluate weed control and dry bean yield in the absence of weed management. Treatments were arranged in a randomized complete block with three replicates in 2009 and four replicates in 2010 and 2011. Each plot was 3 m by 9 m. The PPI, PRE, and POST applications were made on May 29, May 29, and June 29, respectively, in 2009; and on June 2, June 2, and June 23, respectively, in 2010 and 2011.

Weed control was visually assessed on a scale of 0 (no visible weed injury or apparent density reduction) to 100 (complete death or absence of weeds in the plot) at 7 to 10 d after POST herbicide application in all years of the study. Dry bean density was assessed by counting plants within 3 m in the middle two rows of each plot, 4 wk after planting. Dry bean yield was assessed by harvesting 3 m within the middle two rows in 2009 and 2010, and 6 m of the middle two rows in 2011. Plants were harvested on September 10, September 15, and September 27 in 2009, 2010, and 2011, respectively.

All data analyses were performed in R statistical language, version 3.5.1 (https://cran.r-project.org/bin/windows/base/old/3.5.1/) using the lme4 and emmeans packages (Bates et al. 2015; Lenth 2019). Weed control data were arcsine square-root transformed before analysis, and estimated marginal means (predicted means) were back-transformed for presentation. Weed control, dry bean density, and yield were analyzed using a mixed-effects model in which treatments were considered a fixed effect and year was considered a random effect. Estimated marginal means were calculated from the model and post hoc Tukey-adjusted pairwise treatment comparisons were performed ($\alpha = 0.05$) using the emmeans package (Lenth 2019). For dry bean yield, flumioxazin-containing treatments were compared with non-flumioxazin herbicide treatments using a similar mixed-effects model. A linear regression analysis was used to assess the relationship between dry bean density and yield.

Results and Discussion

Flumioxazin-containing herbicide treatments provided at least 98% control of all broadleaf weeds in the study (Figure 1). Flumioxazin plus trifluralin provided better redroot pigweed and hairy nightshade control compared with EPTC plus ethalfluralin, and flumioxazin plus either trifluralin or ethalfluralin provided better control of common lambsquarters compared with imazamox plus bentazon. These results suggest flumioxazin could improve weed control compared with two of the most commonly applied herbicide programs in dry bean.

Flumioxazin significantly reduced dry bean density ($P < 0.001$). Dry bean density 4 wk after planting averaged 53,000 plants ha^{-1} in the three flumioxazin-containing herbicide treatments, compared with 114,600 plants ha^{-1} for all other treatments, including the controls (Figure 2). Crop injury is one of the major concerns in the use of flumioxazin in dry bean. Soltani et al. (2005) showed that small-sized market classes (e.g., white and black beans) were more sensitive to flumioxazin compared with larger-sized market classes (e.g., cranberry and kidney beans). Great northern bean is a

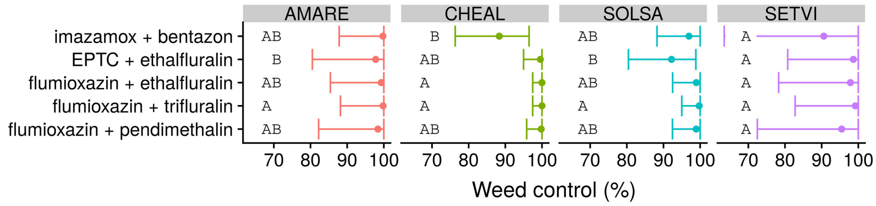

Figure 1. Weed control assessed visually from herbicide treatments, 2009–2011, near Lingle, WY. Points represent estimated marginal means, and bars represent the 95% confidence interval around the estimated marginal mean. Letters on the left side of each panel correspond to mean separation (Tukey honestly significant difference), treatments with the same letter within a panel are not statistically different at the 5% level. AMARE, *Amaranthus retroflexus*, redroot pigweed; CHEAL, *Chenopodium album*, common lambsquarters; SETVI, *Setaria viridis*, green foxtail; SOLSA, *Solanum sarrachoides*, hairy nightshade.

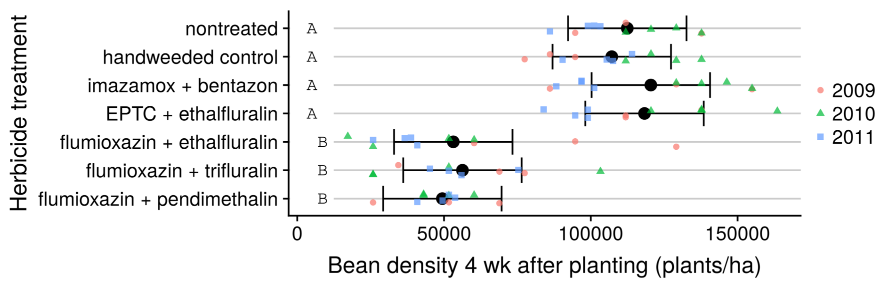

Figure 2. Dry bean population as influenced by herbicide treatments across 3 yr. Each data point represents dry bean population in one plot. Solid black points are the estimated marginal means; horizontal bars indicate 95% confidence intervals. Herbicide treatments are described in Table 1.

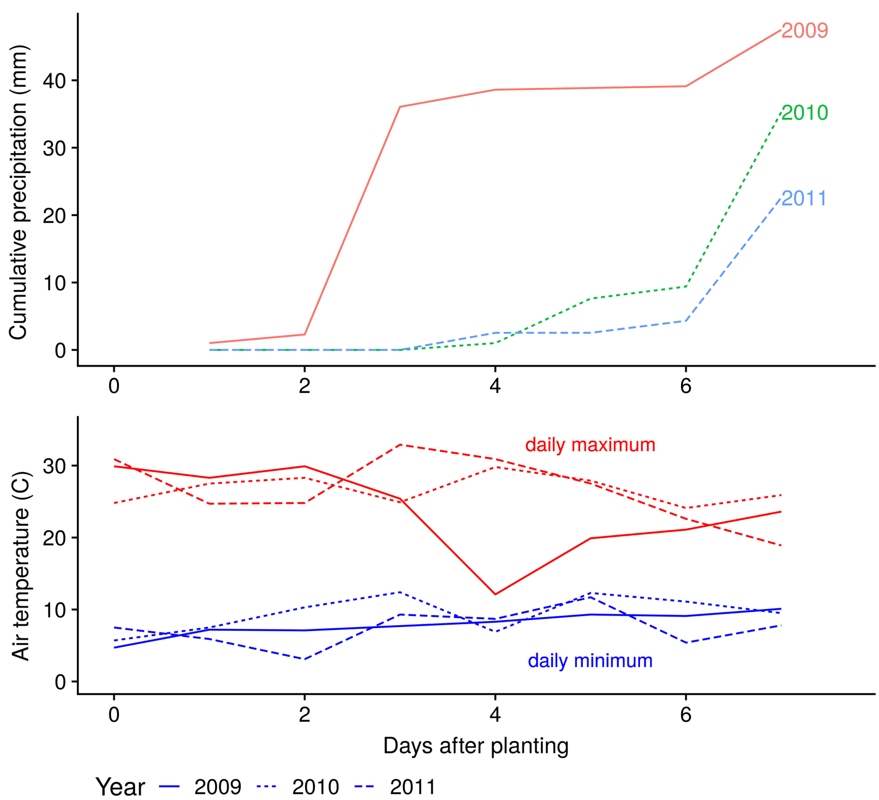

Figure 3. Precipitation and air temperatures 0–7 d after dry bean planting each year of the study.

medium-sized market class, but it has similar sensitivity to flumioxazin as the small-sized market classes used by Soltani et al. (2005). Taylor-Lovell et al. (2001) observed a 19% to 52% reduction in soybean stand counts after flumioxazin application. Phytotoxicity of flumioxazin tends to increase with cool temperatures and high soil moisture levels after herbicide application (Niekamp et al. 1999; Soltani et al. 2005; Taylor-Lovell et al. 2001). In all 3 yr of the study, precipitation events totaling from 11 to 35 mm occurred between 4 and 7 d after planting, when dry bean seedlings were nearly emerging (Figure 3). Thus, high soil moisture levels near emergence could explain the high percentage of crop injury in the flumioxazin treatments.

Table 3. Dry bean yield (estimated marginal means) as influenced by herbicide treatments in 2009–2011, Lingle, WY.

Treatment	Dry bean yield	
	kg ha^{-1}	
Nontreated control	580	C[a]
Hand-weeded control	2,200	A
Flumioxazin + trifluralin	1,600	AB
Flumioxazin + pendimethalin	1,370	BC
Flumioxazin + ethalfluralin	1,660	AB
EPTC + ethalfluralin	2,260	A
Imazamox + bentazon	2,180	AB
P value	<0.001	

[a]Means followed by the same letter are not statistically different according to Tukey honest significantly different test (α = 0.05).

Dry bean yield was correlated with dry bean density (Pearson $r = 0.42$; $P = 0.002$), although yield reduction due to flumioxazin was not as severe as stand reduction. Among individual herbicide treatments, only flumioxazin plus pendimethalin reduced dry bean yield, compared with the hand-weeded control (Table 3). But when combined, flumioxazin treatments averaged 1,540 kg ha^{-1} compared with 2,220 kg ha^{-1} among the herbicide treatments without flumioxazin ($P < 0.001$). These results confirm findings from previous studies. Soltani et al. (2005) observed that flumioxazin applied at 140 g ha^{-1} reduced dry bean yield by 20% to 30%. Similarly, Niekamp et al. (1999) reported that PRE application of flumioxazin resulted in 7% to 18% reduction in soybean yield.

Dry bean yield was affected by dry bean density measured 4 wk after planting; after accounting for bean density, however, the effect of herbicide treatment on yield was not significant ($P > 0.15$). This suggests that flumioxazin did not have a lasting effect on dry bean: The primary effect was on stand reduction within the first 4 wk after planting, and yield loss was a function of the number of surviving dry bean plants (Figure 4). Taylor-Lovell et al. (2001) obtained similar results and reported that soybean was able to grow aggressively to compensate for a certain degree of stand thinning.

It is possible that dry bean stand loss and yield reduction from flumioxazin application observed in this study could be reduced if a larger-seeded dry bean cultivar like pinto bean were planted (Soltani et al. 2005). The effect of soil properties, especially organic matter, on flumioxazin injury in this study is unclear. Soil-applied herbicides bind to organic matter, making them less available in the soil solution. Thus, the low amount of organic matter (1.4% to 1.8%) in this study (Table 1), and compared with the 3.4% to 4.6% organic matter at the study sites of Soltani et al. (2005), may have influenced flumioxazin injury in this study. It is also unclear from this research how much precipitation patterns affected dry bean response to flumioxazin, because substantial precipitation occurred between planting and emergence in all 3 yr of the study. Although Soltani et al. (2005) observed that heavy precipitation after flumioxazin application may have increased dry bean injury, the effect of precipitation on dry bean injury from flumioxazin is a topic that deserves study to better predict when flumioxazin might be used safely. Because dry bean density was the primary predictor of dry bean yield, it is also possible that

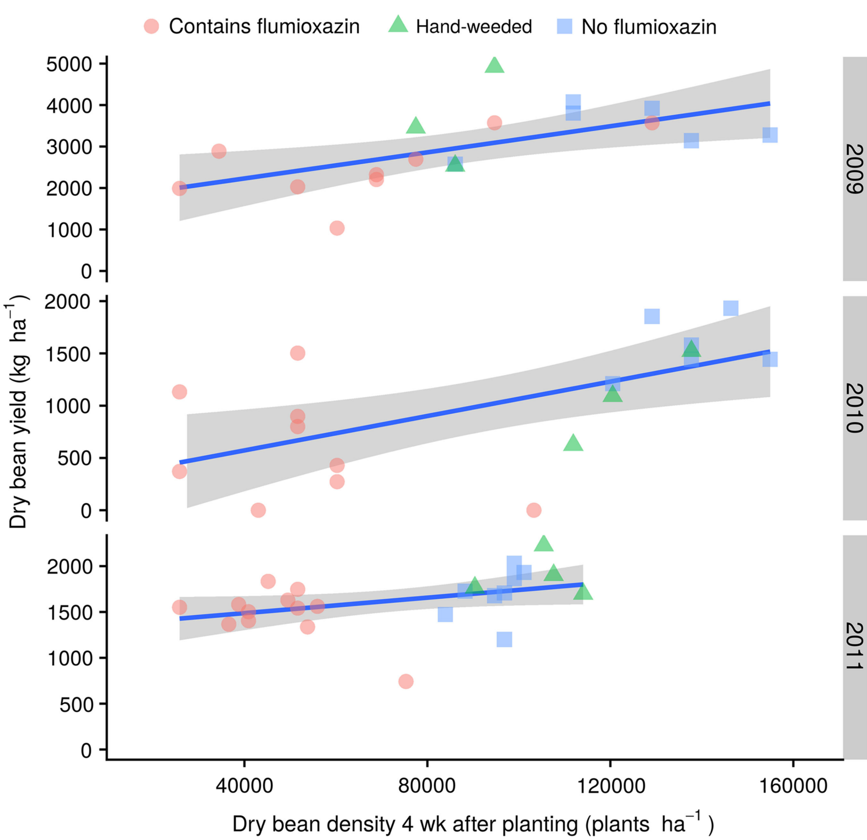

Figure 4. The effect of dry bean density 4 wk after planting on dry bean yield, 2009–2011, near Lingle, WY. Linear regression equations are as follows: 2009: $Y = 1{,}601 + 0.016X$ ($P = 0.026$); 2010: $Y = 243 + 0.008X$ ($P = 0.015$); 2011: $Y = 1{,}319 + 0.004X$ ($P = 0.024$).

increasing seeding density could compensate for stand reduction due to flumioxazin. However, this possibility would require field testing before recommendations are made, because it is currently unknown what seeding density, if any, would maintain acceptable bean density after stand losses caused by flumioxazin. Based on these results, flumioxazin can reduce great northern dry bean density and yield, but higher seeding rates or planting pinto beans or another dry been market class may provide an acceptable margin of safety for flumioxazin use in dry beans.

Acknowledgments. Partial funding for this research was provided by Valent. Funding unrelated to this research has been provided to the University of Wyoming by manufacturers of products used in this research, including Dow AgroSciences, BASF, Gowan Company, and Winfield Solutions.

References

Bates D, Maechler M, Bolker B, Walker S (2015) Fitting linear mixed-effects models using lme4. J Stat Softw 67:1–48

Brandt R, Hussey N (2017) Wyoming Agricultural Statistics 2017. Cheyenne, Wyoming: U.S. Department of Agriculture, National Agricultural Statistics Service. 48 p

Lenth R (2019) emmeans: Estimated marginal means, aka least-squares means. R package, version 1.3.4. =https://CRAN.R-project.org/package=emmeans. Accessed: September 18, 2019

Natural Resources Conservation Service, U.S. Department of Agriculture (2002) Web Soil Survey. https://websoilsurvey.sc.egov.usda.gov/. Accessed: April 8, 2019

Niekamp JW, Johnson WG, Smeda RJ (1999) Broadleaf weed control with sulfentrazone and flumioxazin in no-tillage soybean (*Glycine max*). Weed Technol 13:233–238

Shaner DL, ed (2014) Herbicide Handbook. 10th edn. Lawrence, KS: Weed Science Society of America. Pp 212–213

Soltani N, Bowley S, Sikkema PH (2005) Responses of dry beans to flumioxazin. Weed Technol 19:351–358

Soltani N, Dille JA, Gulden RH, Sprague CL, Zollinger RK, Morishita DW, Lawrence NC, Sbatella GM, Kniss AR, Jha P (2018a) Potential yield loss in dry bean crops due to weeds in the United States and Canada. Weed Technol 32:342–346

Soltani N, Shropshire C, Sildema PH (2018b) Response of dry bean to group 15 herbicides applied preplant incorporated. Can J Plant Sci 98: 1168–1175

Taylor-Lovell S, Wax LM, Nelson R (2001) Phytotoxic response and yield of soybean (*Glycine max*) varieties treated with sulfentrazone or flumioxazin. Weed Technol 15:95–102

Taziar AN, Soltani N, Shropshire C, Robinson DE, Long M, Gillard CL, Sikkema PH (2017) Sulfentrazone plus a low rate of halosulfuron for weed control in white bean (*Phaseolus vulgaris* L.). Agric Sci 8:227

[USDA-NASS] U.S. Department of Agriculture, National Agricultural Statistics Service (2019) Crop Summary 2017. Washington, DC: U.S. Department of Agriculture, National Agricultural Statistics Service. 130 p

Wilson RG (2005) Response of dry bean and weeds to fomesafen and fomesafen tank mixtures. Weed Technol 19:201–206

Wilson RG, Sbatella GM (2014) Integrating irrigation, tillage, and herbicides for weed control in dry bean. Weed Technol 28:479–485