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# Preemergence Herbicides for Potential Use in Potato Production

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Field trials were conducted in 2009 and 2010 near Paterson, WA and Ontario, OR to evaluate weed control and potato tolerance to PRE-applied pyroxasulfone, saflufenacil, and KSU12800 herbicides. Pyroxasulfone at 0.09 to 0.15 kg ai $ha^{-1}$ and saflufenacil at 0.05 to 0.07 kg ai $ha^{-1}$ applied PRE alone or in tank mixes with several currently labeled herbicides did not injure potatoes at either site in both years. KSU12800 at 0.15 kg ai $ha^{-1}$ injured potatoes from 18 to 26% for a period of about 4 wk after emergence at Ontario both years. In addition, KSU12800 at 0.29 and 0.45 kg $ha^{-1}$ injured potatoes from 17 to 38% at 17 d after treatment (DAT) at Paterson in 2009. Pyroxasulfone at 0.15 kg $ha^{-1}$ controlled barnyardgrass, hairy nightshade, and redroot pigweed 96% or greater, but control of common lambsquarters was variable. Saflufenacil at 0.07 kg $ha^{-1}$ provided greater than 93% control of common lambsquarters, hairy nightshade, and redroot pigweed at both sites in 2010. KSU12800 at 0.15 kg $ha^{-1}$ controlled common lambsquarters, hairy nightshade, and redroot pigweed 99% or more at Ontario, but only 87 to 93% at Paterson in 2010. These herbicides did not reduce yield of U.S. no. 1 tubers or total tuber yields compared to standard labeled herbicide treatments when weed control was adequate.
**Nomenclature**: KSU12800; pyroxasulfone; saflufenacil; barnyardgrass, *Echinochloa crus-galli* (L.) Beauv. ECHCG; common lambsquarters, *Chenopodium album* L. CHEAL; hairy nightshade, *Solanum physalifolium* Rusby SOLSA; redroot pigweed, *Amaranthus retroflexus* L. AMARE; potato, *Solanum tuberosum* L. 'Ranger Russet'.
**Key words**: Crop tolerance, herbicide injury, potato injury, weed control, weed management.

Se realizaron experimentos de campo en 2009 y 2010 cerca de Paterson, WA y Ontario, OR para evaluar el control de malezas y la tolerancia de la papa a los herbicidas pyroxasulfone, saflufenacil y KSU12800 aplicados PRE. Se aplicó pyroxasulfone a dosis de 0.09 a 0.15 kg ai $ha^{-1}$ y saflufenacil de 0.05 a 0.07 kg $ha^{-1}$ solos o en mezclas en tanque con varios herbicidas registrados actualmente para papa sin causar daño al cultivo en ninguno de los sitios en ambos años. KSU12800 a 0.15 kg $ha^{-1}$ dañó las papas de 18 a 26% por un período de 4 semanas después de la emergencia, en Ontario en ambos años. Adicionalmente, KSU12800 a 0.29 y 0.45 kg $ha^{-1}$ dañó la papa de 17 a 38% a 17 días después del tratamiento (DAT) en Paterson en 2009. Pyroxasulfone a 0.15 kg $ha^{-1}$ controló *Echinochloa crus-galli*, *Solanum physalifolium* y *Amaranthus retroflexus* 96% o más, pero el control de *Chenopodium album* fue variable. Saflufenacil a 0.07 kg $ha^{-1}$ brindó un control superior a 93% de *C. album*, *S. physalifolium* y *A. retroflexus* en ambos sitios en 2010. KSU12800 a 0.15 kg $ha^{-1}$ controló *C. album*, *S. physalifolium* y *A. retroflexus* 99% o más en Ontario, pero solamente 87 a 93% en Paterson en 2010. Estos herbicidas no redujeron el rendimiento de los tubérculos U.S. no. 1 ni el rendimiento total de tubérculos en comparación con los tratamientos con herbicidas estándar con etiqueta para este cultivo cuando el control de malezas fue adecuado.

Managing weeds is an essential component of potato production because weeds can reduce tuber yields through direct competition with the crop for light, moisture, and nutrients. Weeds also harbor insect, nematode, and disease pests of potatoes (Alvarez and Hutchinson 2005; Boydston et al. 2008b). Current standard weed management programs vary by region and potato variety. In the western United States, standard practices include a hilling operation several weeks after planting, followed by an application of grass- and broadleaf- specific herbicides (Boydston et al. 2008a; Stark and Love 2003). In the United States, metribuzin is applied to more hectares in potato production than any other pesticide, but does not consistently control hairy nightshade, black nightshade (*Solanum nigrum* L.), and cutleaf nightshade (*Solanum triflorum* Nutt.) (Ackley et al. 1996; Anonymous 2005; Eberlein et al. 1994). Metribuzin also injures certain potato varieties (Anonymous 2006; Friesen and Wall 1984). In addition, redroot pigweed, Powell amaranth, (*Amaranthus powellii* S. Wats.) and common lambsquarters resistant to triazine herbicides are present in potato production regions of the United States and Europe (R. Boydston, personal observation; Eleftherohorinos et al. 2000; Heap 2011). Continued development of herbicides with different modes of action is important in order to provide potato producers with tools to manage difficult-to-control weeds and delay development of herbicide-resistant weeds.

Pyroxasulfone and saflufenacil are relatively new herbicides labeled in several annual crops and KSU12800 is an herbicide with potential for use in annual and perennial cropping systems (Kadir et al. 2007; Moran et al. 2011). Pyroxasulfone inhibits biosynthesis of very-long-chain fatty acids and controls many annual grasses, several nightshade species, redroot pigweed, and common lambsquarters in corn (*Zea mays* L.), soybean [*Glycine max* (L.) Merr.], and dry beans (*Phaseolus vulgaris* L.) (Nurse et al. 2011; Sikkema et al. 2007; Tanetani et al. 2009). Saflufenacil inhibits protoporphyri-

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nogen oxidase enzymes in plants and controls numerous annual broadleaf weeds, including redroot pigweed, common lambsquarters, and several nightshade species (Geier et al. 2009; Grossmann et al. 2011; Moran et al. 2011). KSU12800 is a heteroaryl-azole herbicide with broad-spectrum PRE activity on annual broadleaf and grass species (Kadir et al. 2007). These herbicides have not been adequately tested on potatoes, but might be useful tools for weed management in potatoes because they control weed biotypes resistant to metribuzin and rimsulfuron.

These studies were conducted to evaluate Russet potato tolerance and weed response to pyroxasulfone, saflufenacil, and KSU12800 applied PRE after the final hilling operation.

## Materials and Methods

Field trials were conducted in 2009 and 2010 under sprinkler irrigation near Paterson, WA and near Ontario, OR (Table 1). Potato, var. 'Ranger Russet' was planted on March 21, 2009 and March 18, 2010 at Paterson at a seed piece spacing of 22 cm in rows spaced 86 cm apart and April 24, 2009 and April 23, 2010 at Ontario, OR at a seed piece spacing of 23 cm in rows spaced 91 cm apart. Potato hills were harrowed and rehilled (standard grower practice) approximately 10 d prior to potato emergence.

Individual plots were 2.6 by 11 m and herbicide treatments were arranged in a randomized complete block design with four replications. Herbicides were applied with a bicycle sprayer equipped with flat fan nozzles operated at a pressure of 186 kPa in a total spray volume of 187 L $ha^{-1}$. Herbicides were applied April 17, 2009 at Paterson, WA and May 18, 2009 at Ontario, OR after rehilling potatoes and prior to potato emergence. In 2009, pyroxasulfone was tested at 0.09 and 0.15 kg ai $ha^{-1}$ and saflufenacil tested at 0.05 kg ai $ha^{-1}$ (Tables 1 and 2). KSU12800 was applied at 0.29 and 0.45 kg ai $ha^{-1}$ at Paterson in 2009 and at lower rates of 0.15 and 0.22 kg $ha^{-1}$ at Ontario due to early potato injury observed at the Paterson site. KSU12800 was also tested in a tank mix with *S*-metolachlor at 1.1 kg ai $ha^{-1}$ at both sites in 2009. A nontreated weedy check and standard herbicide treatments of flumioxazin at 0.05 kg ai $ha^{-1}$ plus *S*-metolachlor at 1.1 kg $ha^{-1}$ at Paterson, and EPTC at 4.4 kg ai $ha^{-1}$ plus pendimethalin at 0.8 kg ai $ha^{-1}$ plus *S*-metolachlor at1.4 kg $ha^{-1}$ at Ontario were included.

In 2010, herbicides were applied April 19, 2010 at Paterson, WA and May 13, 2010 at Ontario, OR. Pyroxasulfone was tested alone at 0.15 kg $ha^{-1}$ and in tank mixes with herbicides currently labeled in potato; flumioxazin and metribuzin. Saflufenacil at 0.07 kg $ha^{-1}$ and KSU12800 at 0.15 kg $ha^{-1}$ were tested alone and in combination with dimethenamid-P, which is labeled for use in potato. A nontreated weedy check and standard herbicide treatment of flumioxazin (0.05 kg $ha^{-1}$) plus dimethenamid-P (0.7 kg ai $ha^{-1}$) plus metribuzin (0.4 kg ai $ha^{-1}$) were included for comparison.

Both sites were naturally infested with common lambsquarters, hairy nightshade, redroot pigweed, and barnyardgrass. Russian thistle (*Salsola tragus* L.) and large crabgrass [*Digitaria sanguinalis* (L.) Scop.] also were present at the Paterson site in 2010. Primary tillage was conducted according to local recommendations for potato production. Similarly, fertilization, other pest control, and irrigation followed standard potato production practices in the western United States (Strand 2006). In 2009, potato injury and weed

Table 1. Soil properties at the Paterson, WA and Ontario, OR experiment sites and source and formulation of herbicides used in experiments in 2009 and 2010.

| | Paterson, WA | | Ontario, OR | |
|---|---|---|---|---|
| | 2009 | 2010 | 2009 | 2010 |
| Soil characteristics | | | | |
| Soil type | Quincy sand[a] | Quincy sand | Owyhee silt loam[b] | Owyhee silt loam |
| pH | 7.0 | 6.8 | 7.8 | 7.8 |
| Organic matter (%) | 0.5 | 0.4 | 1.9 | 1.5 |
| CEC[c] | 3 | 3 | 10 | 14 |
| Soil texture | | | | |
| Sand (%) | 92 | 92 | 14 | 14 |
| Silt (%) | 5 | 5 | 72 | 72 |
| Clay (%) | 3 | 3 | 14 | 14 |

Herbicide information

| Active ingredient | Trade name/formulation | Source |
|---|---|---|
| Dimethenamid-P | Outlook, 720 g ai $L^{-1}$ | BASF Corp., Research Triangle Park, NC |
| EPTC | Eptam 7E, 840 g ai $L^{-1}$ | Gowan, Yuma, AZ |
| Flumioxazin | Chateau, 51% WG | Valent USA Corp., Greenville, MS |
| KSU12800 | KSU12800, 100 g ai $L^{-1}$ | Kansas State University, Manhattan, KS |
| *S*-metolachlor | Dual II Magnum, 916 g ai $L^{-1}$ | Syngenta Crop Protection Inc., Greensboro, NC |
| Metribuzin | Sencor, 75% WG | Bayer CropScience, Kansas City, MO |
| Pendimethalin | Prowl H2O, 456 g ai $L^{-1}$ | BASF Corp., Research Triangle Park, NC |
| Pyroxasulfone | KIH485 85% WG | Kumiai America, White Plains, NY |
| Saflufenacil | BAS800, 342 g $L^{-1}$ | BASF Corp., Research Triangle Park, NC |

[a] Quincy sand (mixed, mesic xeric torripsamments).

[b] Owyhee silt loam (coarse-silty, mixed, mesic, xerollic camborthid).

[c] Cation exchange capacity.

Table 2. Common lambsquarters and barnyardgrass control following pre-emergence herbicide treatments in potatoes near Paterson, WA and Ontario, OR in 2009.

| Treatment | Rate | Common lambsquarters | | | | Barnyardgrass | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Paterson | | Ontario | | Paterson | | Ontario | |
| | | 27 DAT[a] | 56 DAT | 22 DAT | 66 DAT | 40 DAT | 56 DAT | 45 DAT | 66 DAT |
| | kg ai ha$^{-1}$ | % control | | | | | | | |
| Nontreated | — | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Grower standard[b] | — | 100 | 99 | 100 | 100 | 100 | 100 | 100 | 100 |
| Pyroxasulfone | 0.09 | 87 | 91 | 100 | 100 | 99 | 100 | 100 | 100 |
| Pyroxasulfone | 0.15 | 92 | 90 | 100 | 100 | 100 | 99 | 100 | 100 |
| Saflufenacil | 0.05 | 84 | 75 | 100 | 100 | 64 | 65 | 90 | 93 |
| KSU12800 | 0.15 | — | — | 100 | 100 | — | — | 98 | 99 |
| KSU12800 | 0.22 | — | — | 100 | 100 | — | — | 89 | 93 |
| KSU12800 | 0.29 | 100 | 100 | — | — | 98 | 96 | — | — |
| KSU12800 | 0.45 | 100 | 100 | — | — | 98 | 99 | — | — |
| KSU12800 + *S*-metolachlor | 0.15[c] + 1.1 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| LSD P = 0.05 | | 7 | 9 | — | — | 12 | 14 | 7 | 5 |

[a] Abbreviation: DAT, days after treatment.

[b] Grower standard treatments were tank mixes of flumioxazin at 0.05 kg ai ha$^{-1}$ plus *S*-metolachlor at 1.1 kg ai ha$^{-1}$at Paterson, WA and EPTC at 4.4 kg ai ha$^{-1}$ plus pendimethalin at 0.8 kg ai ha$^{-1}$ plus *S*-metolachlor at 1.4 kg ai ha$^{-1}$ at Ontario, OR.

[c] KSU12800 was tested at 0.29 kg ai ha$^{-1}$ at Paterson, WA in a tank mix with *S*-metolachlor.

control were rated visually on a scale of 0 = no injury/no control to 100 = death/complete control at 17, 27, 40, and 56 d after herbicide treatment (DAT) and at 8, 22, 45, and 66 DAT at Paterson and Ontario, respectively. In 2010, potato injury and weed control were visually rated at 25, 32, 49, and 92 days and at 35, 54, and 102 DAT at Paterson and Ontario, respectively. Potato yield was determined on September 4, 2009 and October 5, 2010 at Paterson, WA and August 30, 2009 and September 15, 2010 at Ontario, OR by weighing tubers mechanically harvested from 9 m of the center row of each 3-row plot. Tubers from each plot were graded by size and quality according to USDA grading standards (Anonymous 1991). U.S. No. 1 potatoes were grouped into three size categories; 113 to 226 g, 226 to 339 g, and > 339 g and the percentage by weight in each category determined. Specific gravity was measured on ten, 230- to 280-g tubers in each treatment at the Paterson site in both years.

Analysis of variance was performed using SAS (2008) PROC GLM procedure. Data were pooled across sites when no significant site or site by treatment interactions occurred. Mean separations were performed using Fisher's protected least significant difference test at $\alpha = 0.05$.

## Results and Discussion

Analysis of variance results for weed control and potato injury evaluations were similar for several dates each year; thus not all dates from each year are presented.

**2009 Weed Control.** Common lambsquarters, hairy nightshade, redroot pigweed, and barnyardgrass were the most prevalent weed species at both sites, averaging 107, 21, 1, and 21 plants m$^{-2}$ at Paterson and 2, 3, 6, and 1 plants m$^{-2}$ at Ontario in nontreated checks, respectively. There was a significant site by treatment interaction for control of all weed species, except hairy nightshade at the two later evaluation dates; therefore, weed control data are presented separately for each site (Tables 2 and 3). KSU12800 alone and in tank mixtures with *S*-metolachlor completely controlled common lambsquarters at both sites (Table 2). Pyroxasulfone at 0.09 and 0.15 kg ha$^{-1}$ controlled common lambsquarters from 87 to 92% at Paterson and completely controlled the weed season-long at Ontario. Nurse et al. (2011) reported that common lambsquarters was less susceptible to pyroxasulfone than redroot pigweed and doses of 0.5 kg ha$^{-1}$ were required to reduce common lambsquarters biomass by 90%. Saflufenacil at 0.05 kg ha$^{-1}$ did not control common lambsquarters adequately at the Paterson site, but completely controlled the weed at Ontario (Table 2). The excellent control of common lambsquarters with pyroxasulfone and saflufenacil at the Ontario site was probably due to a combination of a later planting date and lower population density than at the Paterson site. Common lambsquarters tends to emerge earlier than many summer annual weeds; the earlier planting date at the Paterson site likely favored common lambsquarters over later germinating species (Ogg and Dawson, 1984).

Pyroxasulfone at 0.09 and 0.15 kg ha$^{-1}$ and KSU12800 tank mixed with *S*-metolachlor controlled barnyardgrass from 99 to 100% at both sites (Table 2). Saflufenacil at 0.05 kg ha$^{-1}$ controlled barnyardgrass only 64 to 65% at the Paterson site and 90 to 93% at the Ontario site. Saflufenacil typically does not control grass weeds, but can injure grass crops such as proso millet when applied at rates of 0.05 kg ha$^{-1}$ and sweet corn when applied pre-emergence at 0.05 to 0.1 kg ha$^{-1}$ (Lyon and Kniss 2010; Robinson et al. 2012). The greater barnyardgrass control observed at Ontario was likely due to a low population density of the weed at the Ontario site. KSU12800 at 0.29 and 0.45 kg ha$^{-1}$ controlled barnyardgrass at Paterson 96 to 99%, whereas lower rates of 0.15 and 0.22 kg ha$^{-1}$ at Ontario controlled barnyardgrass 98% and 89%, respectively at 45 DAT (Table 2). The grower standard herbicide treatment controlled all weeds at both sites.

Pyroxasulfone, saflufenacil, and KSU12800 completely controlled hairy nightshade at both sites by 56 and 66 DAT and redroot pigweed at the Paterson site (Table 3). Pyroxasulfone at 0.09 and 0.15 kg ha$^{-1}$ also completely controlled

Table 3. Hairy nightshade and redroot pigweed control following pre-emergence herbicide treatments in potatoes near Paterson, WA and Ontario, OR in 2009.

| | | Hairy nightshade | | | | Redroot pigweed | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Paterson | | Ontario | | Paterson | | Ontario | |
| Treatment | Rate | 27 DAT[a] | 56 DAT | 22 DAT | 66 DAT | 27 DAT | 56 DAT | 22 DAT | 66 DAT |
| | kg ai ha$^{-1}$ | % control | | | | | | | |
| Nontreated | — | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Grower standard[b] | — | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| Pyroxasulfone | 0.09 | 99 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| Pyroxasulfone | 0.15 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| Saflufenacil | 0.05 | 95 | 100 | 100 | 100 | 100 | 100 | 95 | 98 |
| KSU12800 | 0.15 | — | — | 100 | 100 | — | — | 100 | 99 |
| KSU12800 | 0.22 | — | — | 100 | 100 | — | — | 99 | 95 |
| KSU12800 | 0.29 | 100 | 100 | — | — | 100 | 100 | — | — |
| KSU12800 | 0.45 | 100 | 100 | — | — | 99 | 100 | — | — |
| KSU12800 + *S*-metolachlor | 0.15[c] + 1.1 | 100 | 100 | 99 | 100 | 100 | 100 | 100 | 100 |
| LSD P = 0.05 | | 2 | — | 1 | — | 1 | — | 3 | 2 |

[a] Abbreviation: DAT, days after treatment.

[b] Grower standard treatments were tank mixes of flumioxazin at 0.05 kg ai ha$^{-1}$ plus *S*-metolachlor at 1.1 kg ai ha$^{-1}$at Paterson, WA and EPTC at 4.4 kg ai ha$^{-1}$ plus pendimethalin at 0.8 kg ai ha$^{-1}$ plus *S*-metolachlor at 1.4 kg ai ha$^{-1}$ at Ontario, OR.

[c] KSU12800 was tested at 0.29 kg ai ha$^{-1}$ at Paterson, WA in a tank mix with *S*-metolachlor.

redroot pigweed at Ontario. Saflufenacil at 0.05 kg ha$^{-1}$controlled pigweed from 95 to 98% at Ontario. KSU12800 at 0.15 and 0.22 kg ha$^{-1}$ initially controlled redroot pigweed 99 to 100% at Ontario at 22 DAT, but control decreased to 95% by 66 DAT with the 0.22 kg ha$^{-1}$ rate (Table 3). A tank mix of KSU12800 with *S*-metolachlor completely controlled redroot pigweed at both sites.

**2009 Potato Response and Tuber Yield.** There was a site-by-treatment interaction for early season potato injury; therefore, data are presented separately for each site (Table 4). KSU12800 caused chlorosis of newly emerging potato leaves for about 3 wk after application, ranging from 17 to 38%, which dissipated at later evaluation dates at both locations (Table 4). Because the Paterson site was planted about 1 mo earlier than Ontario, once the early season potato injury with KSU12800 at 0.29 to 0.45 kg ha$^{-1}$ was observed, the rates were reduced to 0.15 and 0.22 kg ha$^{-1}$ at Ontario. Tank mixing KSU12800 at 0.29 kg ha$^{-1}$ with *S*-metolachlor increased early season potato injury from 17 to 29% at Paterson, but not at Ontario when using a lower KSU12800 rate of 0.15 kg ha$^{-1}$. No significant potato injury was observed following pyroxasulfone at 0.09 and 0.15 kg ha$^{-1}$ or saflufenacil at 0.05 kg ha$^{-1}$ at either site. By 56 and 66 DAT, no potato injury was evident from any of the herbicide treatments at Paterson and Ontario, respectively (Table 4).

There was a significant site effect and a significant site by herbicide treatment interaction for U.S. No. 1 and total potato tuber yield so the data are presented separately for each site (Table 5). At Paterson, U.S. No. 1 and total tuber yield in nontreated weedy controls averaged only 33 and 43 metric tons (MT) ha$^{-1}$ whereas the standard herbicide treatment averaged 81 and 90 MT ha$^{-1}$, respectively (Table 5). Annual weeds competing in potatoes season-long reduced tuber yield

Table 4. Potato injury following treatment with pre-emergence herbicides near Paterson, WA and Ontario, OR in 2009.

| | | Potato injury | | | | | |
|---|---|---|---|---|---|---|---|
| | | Paterson | | | Ontario | | |
| Treatment | Rate | 17 DAT[a] | 40 DAT | 56 DAT | 22 DAT | 45 DAT | 66 DAT |
| | kg ai ha$^{-1}$ | % | | | | | |
| Nontreated | — | 0 | 0 | 0 | 0 | 0 | 0 |
| Grower standard[b] | — | 1 | 1 | 0 | 0 | 0 | 0 |
| Pyroxasulfone | 0.09 | 2 | 0 | 0 | 0 | 0 | 0 |
| Pyroxasulfone | 0.15 | 1 | 0 | 0 | 0 | 0 | 0 |
| Saflufenacil | 0.05 | 0 | 0 | 0 | 0 | 0 | 0 |
| KSU12800 | 0.15 | — | — | — | 18 | 2 | 0 |
| KSU12800 | 0.22 | — | — | — | 19 | 5 | 0 |
| KSU12800 | 0.29 | 17 | 2 | 0 | — | — | — |
| KSU12800 | 0.45 | 38 | 6 | 0 | — | — | — |
| KSU12800 + *S*-metolachlor | 0.15[c] + 1.1 | 29 | 5 | 0 | 19 | 5 | 0 |
| LSD P = 0.05 | | 7 | 2 | — | 3 | — | — |

[a] Abbreviation: DAT, days after treatment.

[b] Grower standard treatments were tank mixes of flumioxazin at 0.05 kg ai ha$^{-1}$ plus *S*-metolachlor at 1.1 kg ai ha$^{-1}$at Paterson, WA and EPTC at 4.4 kg ai ha$^{-1}$ plus pendimethalin at 0.8 kg ai ha$^{-1}$ plus *S*-metolachlor at 1.4 kg ai ha$^{-1}$ at Ontario, OR.

[c] KSU12800 was tested at 0.29 kg ai ha$^{-1}$ at Paterson, WA in a tank mix with *S*-metolachlor.

Table 5. Potato yield in metric tons (MT) following pre-emergence herbicide treatments near Paterson, WA and Ontario, OR in 2009.

| Treatment | Rate | Potato tuber yield | | | | | |
|---|---|---|---|---|---|---|---|
| | | Paterson | | | Ontario | | |
| | | < 113 g | U.S. No. 1[a] | Total | < 113 g | U.S. No. 1 | Total |
| | kg ai ha$^{-1}$ | MT ha−1 | | | | | |
| Nontreated | — | 9 | 33 | 43 | 6 | 43 | 50 |
| Grower standard[b] | — | 6 | 81 | 90 | 6 | 54 | 60 |
| Pyroxasulfone | 0.09 | 6 | 73 | 81 | 5 | 52 | 59 |
| Pyroxasulfone | 0.15 | 6 | 67 | 76 | 5 | 50 | 57 |
| Saflufenacil | 0.05 | 7 | 55 | 62 | 5 | 55 | 62 |
| KSU12800 | 0.15 | — | — | — | 7 | 55 | 65 |
| KSU12800 | 0.22 | — | — | — | 5 | 47 | 54 |
| KSU12800 | 0.29 | 6 | 74 | 84 | — | — | — |
| KSU12800 | 0.45 | 6 | 82 | 93 | — | — | — |
| KSU12800 + *S*-metolachlor | 0.15[c] + 1.1 | 4 | 79 | 89 | 5 | 57 | 63 |
| LSD P = 0.05 | | NS[d] | 12 | 12 | NS | 8 | 8 |

[a] U.S. No. 1 tubers have no defects and weigh ≥ 113 g.

[b] Grower standard treatments were tank mixes of flumioxazin at 0.05 kg ai ha$^{-1}$ plus *S*-metolachlor at 1.1 kg ai ha$^{-1}$at Paterson, WA and EPTC at 4.4 kg ai ha$^{-1}$ plus pendimethalin at 0.8 kg ai ha$^{-1}$ plus *S*-metolachlor at 1.4 kg ai ha$^{-1}$ at Ontario, OR.

[c] KSU12800 was tested at 0.29 kg ai ha$^{-1}$ at Paterson, WA in a tank mix with *S*-metolachlor.

[d] NS = no significant difference at the < 0.05 probability level.

54% in North Dakota studies (Nelson and Thoreson 1981). Marketable tuber yield of russet potato planted in mineral soils was reduced 28% and 66 to 81% by annual weeds in Washington and Michigan, respectively (Boydston 2007; Vangessel and Renner 1990). At Paterson, pyroxasulfone at 0.15 kg ha$^{-1}$ and saflufenacil at 0.05 kg ha$^{-1}$ reduced U.S. No. 1 and total tuber yield compared to the standard herbicide treatment, probably due to incomplete control of common lambsquarters (Tables 2 and 5). However, the lower rate of 0.09 kg ha$^{-1}$ pyroxasulfone did not significantly reduce tuber yields compared to the standard herbicide treatment despite poor control of common lambsquarters. Perhaps the higher rate of 0.15 kg ha$^{-1}$ pyroxasulfone contributed to lower U.S. No. 1 tuber yields or the plots treated with the lower rate had a lower common lambsquarters population by chance. At both sites, U.S. No. 1 and total tuber yield of plots treated with KSU12800 were similar to plots treated with the standard herbicide despite early-season visual injury observed on potato treated with KSU12800 (Tables 4 and 5).

Potato U.S. No. 1 and total tuber yield of nontreated weedy controls at Ontario averaged 43 and 50 MT ha$^{-1}$, whereas the standard herbicide treatment averaged 54 and 60 MT ha$^{-1}$, respectively (Table 5). Weed densities in nontreated controls at Ontario were lower than weed densities at Paterson, resulting in a lower impact on potato tuber yield at Ontario. At Ontario, U.S. No. 1 tuber yield did not differ significantly among all herbicide-treated plots.

There were few differences in total tuber yield among herbicide-treated plots with the exception of KSU12800 at 0.22 kg ha$^{-1}$ having a significantly lower yield than KSU12800 at 0.15 kg ha$^{-1}$ alone or tank mixed with metolachlor (Table 5). Yield of small tubers (< 113 g) was not affected by weed control treatment at either site, although there was a strong trend toward a greater yield of small tubers in the nontreated weedy control plots at the Paterson site (Table 5).

Nontreated weedy controls had a greater percentage of U.S. No. 1 tubers in the smallest size category (113 to 226 g) and lower percentage of tubers in the largest size category (>339 g) compared to herbicide-treated plots at Paterson (Table 6). Similarly, plots treated with pyroxasulfone at 0.15 kg ha$^{-1}$ and saflufenacil at 0.05 kg ha$^{-1}$ had a greater percentage of tubers in the smaller size category and fewer in the larger size category compared to the standard herbicide treatment, likely a result of poor control of common lambsquarters with these treatments. Average tuber size was reduced by annual weed competition with potato in earlier-reported studies (Nelson and Thornsen 1981). At Ontario, tuber size distribution within U.S. no. 1 was not significantly affected by weed control treatments, although a similar trend toward a greater percentage of smaller tubers was observed in the nontreated weedy controls (Table 6). Tuber specific gravity was not significantly affected by herbicide treatment at Paterson and averaged 1.08 (data not shown).

**2010 Weed Control.** There was a significant site by treatment interaction for control ratings of all weed species, so weed control data are presented separately for each site (Tables 7 and 8). Common lambsquarters, hairy nightshade, redroot pigweed, and barnyardgrass populations in nontreated checks averaged 2, 4, 1, and 2 plants m$^{-2}$ and 4, 4, 7, 1 plants m$^{-2}$ at Paterson and Ontario, respectively. At Ontario, KSU12800 alone at 0.15 kg ha$^{-1}$ controlled common lambsquarters 89% and 87% at 49 and 92 DAT, respectively, at Paterson (Table 7). Pyroxasulfone alone at 0.15 kg ha$^{-1}$ controlled common lambsquarters 92% at 92 DAT. All other herbicide treatments controlled common lambsquarters from 94 to 99% at Paterson. At Ontario, common lambsquarters control was least with pyroxasulfone at 0.15 kg ha$^{-1}$ averaging 89 and 86% control at 54 and 102 DAT, respectively. Tank mixing flumioxazin or metribuzin with pyroxasulfone improved common lambsquarters control. All other herbicide treatments controlled common lambsquarters similar to the

Table 6. U.S. No. 1[a] tuber size distribution following pre-emergence herbicide treatments near Paterson, WA and Ontario, OR in 2009.

| Treatment | Rate | Percentage (by weight) of U.S. No. 1 tubers[a] | | | | | |
|---|---|---|---|---|---|---|---|
| | | Paterson | | | Ontario | | |
| | | 113–226 g | 226–339 g | > 339 g | 113–226 g | 226–339 g | > 339 g |
| | kg ai ha$^{-1}$ | % | | | | | |
| Nontreated | — | 51 | 47 | 2 | 24 | 56 | 21 |
| Grower standard[b] | — | 11 | 52 | 36 | 16 | 53 | 30 |
| Pyroxasulfone | 0.09 | 18 | 55 | 27 | 17 | 53 | 30 |
| Pyroxasulfone | 0.15 | 23 | 54 | 22 | 19 | 45 | 36 |
| Saflufenacil | 0.05 | 24 | 60 | 16 | 16 | 48 | 37 |
| KSU12800 | 0.15 | — | — | — | 15 | 51 | 34 |
| KSU12800 | 0.22 | — | — | — | 17 | 53 | 29 |
| KSU12800 | 0.29 | 15 | 49 | 35 | — | — | — |
| KSU12800 | 0.45 | 15 | 50 | 35 | — | — | — |
| KSU12800 + *S*-metolachlor | 0.15[c] + 1.1 | 14 | 45 | 40 | 18 | 54 | 28 |
| LSD P = 0.05 | | 8 | 7 | 11 | NS[d] | NS | NS |

[a] U.S. No. 1 tubers have no defects and weigh ≥ 113 g.

[b] Grower standard treatments were tank mixes of flumioxazin at 0.05 kg ai ha$^{-1}$ plus *S*-metolachlor at 1.1 kg ai ha$^{-1}$at Paterson, WA and EPTC at 4.4 kg ai ha$^{-1}$ plus pendimethalin at 0.8 kg ai ha$^{-1}$ plus *S*-metolachlor at 1.4 kg ai ha$^{-1}$ at Ontario, OR.

[c] KSU12800 was tested at 0.29 kg ai ha$^{-1}$ at Paterson, WA in a tank mix with *S*-metolachlor.

[d] NS = no significant difference at the < 0.05 probability level.

Table 7. Common lambsquarters and barnyardgrass control following pre-emergence herbicide treatments in potatoes near Paterson, WA and Ontario, OR in 2010.

| Treatment | Rate | Common lambsquarters | | | | Annual grass[a] | | Barnyardgrass | |
|---|---|---|---|---|---|---|---|---|---|
| | | Paterson | | Ontario | | Paterson | | Ontario | |
| | | 49 DAT[b] | 92 DAT | 54 DAT | 102 DAT | 49 DAT | 92 DAT | 54 DAT | 102 DAT |
| | kg ai ha$^{-1}$ | % control | | | | | | | |
| Nontreated | — | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Grower standard[c] | — | 99 | 96 | 100 | 100 | 98 | 94 | 100 | 100 |
| Pyroxasulfone | 0.15 | 95 | 92 | 89 | 86 | 98 | 98 | 100 | 100 |
| Pyroxasulfone + flumioxazin | 0.15 + 0.05 | 98 | 98 | 95 | 94 | 96 | 96 | 100 | 100 |
| Pyroxasulfone + metribuzin | 0.15 + 0.39 | 95 | 95 | 100 | 100 | 96 | 97 | 100 | 100 |
| Saflufenacil | 0.07 | 98 | 99 | 96 | 93 | 75 | 78 | 97 | 96 |
| Saflufenacil + dimethenamid-P | 0.07 + 0.74 | 96 | 96 | 99 | 98 | 95 | 94 | 100 | 100 |
| KSU12800 | 0.15 | 89 | 87 | 100 | 100 | 80 | 86 | 75 | 75 |
| KSU12800 + dimethenamid-P | 0.15 + 0.74 | 94 | 95 | 100 | 100 | 96 | 99 | 100 | 100 |
| LSD P = 0.05 | | 6 | 6 | 6 | 8 | 13 | 8 | 23 | 23 |

[a] Annual grasses consisted of a mix of large crabgrass and barnyardgrass at Paterson, WA.

[b] Abbreviation: DAT, days after treatment.

[c] Grower standard treatment was a tank mix of metribuzin at 0.39 kg ai ha$^{-1}$ plus dimethenamid-P at 0.74 kg ai ha$^{-1}$ plus flumioxazin at 0.05 kg ai ha$^{-1}$.

Table 8. Hairy nightshade and redroot pigweed control following pre-emergence herbicide treatments in potatoes near Paterson, WA and Ontario, OR in 2010.

| Treatment | Rate | Hairy nightshade | | | | Redroot pigweed | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Paterson | | Ontario | | Paterson | | Ontario | |
| | | 49 DAT[a] | 92 DAT | 54 DAT | 102 DAT | 49 DAT | 92 DAT | 54 DAT | 102 DAT |
| | kg ai ha$^{-1}$ | % control | | | | | | | |
| Nontreated | — | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Grower standard[b] | — | 99 | 99 | 100 | 100 | 99 | 94 | 100 | 100 |
| Pyroxasulfone | 0.15 | 97 | 96 | 100 | 100 | 99 | 99 | 100 | 100 |
| Pyroxasulfone + flumioxazin | 0.15 + 0.05 | 99 | 99 | 100 | 100 | 98 | 93 | 100 | 100 |
| Pyroxasulfone + metribuzin | 0.15 + 0.39 | 96 | 97 | 100 | 100 | 100 | 98 | 100 | 100 |
| Saflufenacil | 0.07 | 97 | 98 | 100 | 100 | 100 | 99 | 97 | 97 |
| Saflufenacil + dimethenamid-P | 0.07 + 0.74 | 98 | 97 | 100 | 100 | 99 | 99 | 100 | 100 |
| KSU12800 | 0.15 | 88 | 91 | 100 | 100 | 93 | 91 | 100 | 100 |
| KSU12800 + dimethenamid-P | 0.15 + 0.74 | 95 | 94 | 100 | 100 | 98 | 91 | 100 | 100 |
| LSD P = 0.05 | | 4 | 4 | — | — | 3 | 7 | 2 | 2 |

[a] Abbreviation: DAT, days after treatment.

[b] Grower standard treatment was a tank mix of metribuzin at 0.39 kg ai ha$^{-1}$ plus dimethenamid-P at 0.74 kg ai ha$^{-1}$ plus flumioxazin at 0.05 kg ai ha$^{-1}$.

Table 9. Potato yield in metric tons (MT) following pre-emergence herbicide treatments near Paterson, WA and Ontario, OR in 2010.

| | | Potato tuber yield | | | | | |
|---|---|---|---|---|---|---|---|
| | | Paterson | | | Ontario | | |
| Treatment | Rate | < 113 g | U.S. No. 1[a] | Total | < 113 g | U.S. No. 1 | Total |
| | kg ai ha$^{-1}$ | MT ha−1 | | | | | |
| Nontreated | — | 9 | 47 | 56 | 18 | 10 | 28 |
| Grower standard[b] | — | 6 | 61 | 68 | 11 | 46 | 59 |
| Pyroxasulfone | 0.15 | 5 | 60 | 66 | 16 | 34 | 51 |
| Pyroxasulfone + flumioxazin | 0.15 + 0.05 | 4 | 67 | 73 | 14 | 45 | 61 |
| Pyroxasulfone + metribuzin | 0.15 + 0.39 | 4 | 66 | 73 | 13 | 48 | 63 |
| Saflufenacil | 0.07 | 5 | 63 | 69 | 15 | 44 | 61 |
| Saflufenacil + dimethenamid-P | 0.07 + 0.74 | 5 | 67 | 74 | 11 | 52 | 65 |
| KSU12800 | 0.15 | 6 | 52 | 59 | 12 | 40 | 55 |
| KSU12800 + dimethenamid-P | 0.15 + 0.74 | 5 | 57 | 64 | 10 | 53 | 65 |
| LSD P = 0.05 | — | 2 | 9 | 10 | 4 | 10 | 8 |

[a] U.S. No. 1 tubers have no defects and weigh $\geq$ 113 g.

[b] Grower standard treatment was a tank mix of metribuzin at 0.39 kg ai ha$^{-1}$ plus dimethenamid-P at 0.74 kg ai ha$^{-1}$ plus flumioxazin at 0.05 kg ai ha$^{-1}$.

standard herbicide treatment, ranging from 93 to 100% control at 102 DAT (Table 7).

At Paterson in 2010, both large crabgrass and barnyardgrass were present. All herbicide treatments controlled annual grass weeds 94% or more except saflufenacil alone at 0.07 kg ha$^{-1}$ and KSU12800 alone at 0.15 kg ha$^{-1}$, which did not provide adequate annual grass control (Table 7). Similarly at Ontario, barnyardgrass was completely controlled by all herbicide treatments except saflufenacil alone at 0.07 kg ha$^{-1}$ and KSU12800 alone at 0.15 kg ha$^{-1}$. Tank mixing both herbicides with dimethenamid-P at 0.74 kg ha$^{-1}$ improved grass control at Paterson and increased grass control with KSU12800 at Ontario (Table 7).

Pyroxasulfone at 0.15 kg ha$^{-1}$ and saflufenacil at 0.07 kg ha$^{-1}$ applied alone or in tank mixes with flumioxazin, metribuzin, or dimethenamid-P, controlled hairy nightshade from 96 to 100% at both sites in 2010 (Table 8). KSU12800 at 0.15 kg ha$^{-1}$ controlled hairy nightshade 88% at 49 DAT at the Paterson site and tank mixing KSU12800 with dimethenamid-P improved hairy nightshade control to 95%. KSU12800 alone or tank mixed with dimethenamid-P completely controlled hairy nightshade at the Ontario site (Table 8).

Redroot pigweed control at 49 DAT was least with KSU12800 alone at 0.15 kg ha$^{-1}$ at the Paterson site averaging 93% (Table 8). By 92 DAT, all herbicide treatments controlled redroot pigweed similar to the standard herbicide treatment ranging from 91 to 99% control. At Ontario, all herbicide treatments completely controlled red root pigweed except saflufenacil at 0.07 kg ha$^{-1}$, which averaged 97% control. At Paterson, Russian thistle was controlled 98% or more by all herbicide treatments except pyroxasulfone alone at 0.15 kg ha$^{-1}$ which averaged only 68% control at 49 DAT (data not shown).

**2010 Potato Response and Tuber Yield.** There was a site-by-treatment interaction for early season potato injury. No potato injury was observed with any herbicide treatments at Paterson in 2010 (data not shown). However, a severe wind storm on May 4, 2010 followed by freezing air temperatures on May 5, 2010 killed all early-emerged potato shoots, so any possible early herbicide injury symptoms on potatoes were missed. No potato injury was observed when new shoots emerged following the freezing event. At Ontario, KSU12800 at 0.15 kg ha$^{-1}$ caused chlorosis of emerging potato leaves averaging 26% injury at 35 DAT when applied alone and 21% when applied in a tank mix with dimethenamid-P (data not shown). No potato injury was observed with other herbicide treatments at 35 DAT and no injury was observed at later evaluation dates (data not shown).

There was a significant site and site by treatment effect for the yield of U.S. No.1 and tubers < 113 g, so data are presented separately for each site (Table 9). At Paterson, U.S. No. 1 and total tuber yield of nontreated weedy controls averaged 47 and 56 MT ha$^{-1}$, whereas the standard herbicide treatment averaged 61 and 68 MT ha$^{-1}$, respectively. Nontreated weedy controls also yielded more tubers < 113 g than all herbicide-treated plots. Potato U.S. No. 1 tuber yield and total tuber yield of all experimental herbicide treatments were not significantly different from the standard herbicide treatment at Paterson (Table 9).

U.S. No. 1 and total tuber yield of nontreated weedy controls at Ontario averaged 10 and 28 MT ha$^{-1}$, whereas the standard herbicide treatment averaged 46 and 59 MT ha$^{-1}$, respectively (Table 9). At Ontario, 64% of the total tuber yield consisted of tubers < 113g and only 36% U.S. No. 1. U.S. No. 1 and total tuber yield of all herbicide treatments was not significantly different from the standard herbicide treatment with the exception of pyroxasulfone at 0.15 kg ha$^{-1}$, in which U.S. no. 1 yield and total tuber yield were 26 and 14% lower, respectively, than that of the standard herbicide treatment. U.S. No. 1 yield and total tuber yield of KSU12800 plus dimethenamid-P was greater than that of KSU12800 applied alone at Ontario, likely due to the improved grass control with the tank mix (Table 10). Potatoes treated with pyroxasulfone and saflufenacil alone also had a greater yield of tubers < 113 g, similar to the nontreated weedy controls. Lower tuber yields with pyroxasulfone applied alone were attributed to poor common lambsquarters control, whereas saflufenacil alone did not completely control common lambsquarters and barnyardgrass. Potatoes treated with tank mixes of pyroxasulfone with either flumioxazin or

Table 10. U.S. No. 1[a] tuber size distribution following pre-emergence herbicide treatments near Paterson, WA and Ontario, OR in 2010.

| | | Percentage (by weight) of U.S. No. 1 tubers[a] | | | | | |
|---|---|---|---|---|---|---|---|
| | | Paterson | | | Ontario | | |
| Treatment | Rate | 113–226 g | 226–339 g | > 339 g | 113–226 g | 226–339 g | > 339 g |
| | kg ai ha$^{-1}$ | % | | | | | |
| Nontreated | — | 33 | 56 | 11 | 66 | 34 | 0 |
| Grower standard[b] | — | 17 | 56 | 27 | 32 | 57 | 11 |
| Pyroxasulfone | 0.15 | 16 | 53 | 31 | 41 | 50 | 9 |
| Pyroxasulfone + flumioxazin | 0.15 + 0.05 | 11 | 49 | 40 | 35 | 53 | 12 |
| Pyroxasulfone + metribuzin | 0.15 + 0.39 | 11 | 50 | 39 | 32 | 56 | 12 |
| Saflufenacil | 0.07 | 17 | 55 | 28 | 36 | 55 | 9 |
| Saflufenacil + dimethenamid-P | 0.07 + 0.74 | 15 | 49 | 36 | 25 | 59 | 16 |
| KSU12800 | 0.15 | 25 | 60 | 15 | 35 | 50 | 15 |
| KSU12800 + dimethenamid-P | 0.15 + 0.74 | 19 | 56 | 25 | 25 | 55 | 20 |
| LSD P = 0.05 | — | 6 | NS[c] | 9 | 17 | 14 | 8 |

[a] U.S. No. 1 tubers have no defects and weigh $\geq$ 113 g.
[b] Grower standard treatment was a tank mix of metribuzin at 0.39 kg ai ha$^{-1}$ plus dimethenamid-P at 0.74 kg ai ha$^{-1}$ plus flumioxazin at 0.05 kg ai ha$^{-1}$.
[c] NS = no significant difference at the $<$ 0.05 probability level.

metribuzin yielded similar amount of U.S. No. 1 and total tuber yield as the standard herbicide treatment (Table 9).

Nontreated weedy controls had a greater percentage of U.S. No. 1 tubers in the smallest size category (113 to 226 g) and a lower percentage of tubers in the largest size category (> 339 g) compared to herbicide-treated plots at both sites (Table 10). At Paterson, KSU12800 at 0.15 kg ha$^{-1}$ applied alone had a greater percentage of 113 to 226 g tubers and a lower percentage of tubers > 339 g than the standard herbicide treatment, probably due to poor weed control with KSU applied alone. Pyroxasulfone tank mixed with either flumioxazin or metribuzin increased the percentage of tubers in the > 339 g category and decreased the percentage in the 113 to 226 g category compared to the standard herbicide treatment at Paterson (Table 10).

At Ontario, there were no significant differences in the percentage of U.S. No. 1 tubers in the 113 to 226 g and 226 to 339 g size categories among the herbicide treatments tested (Table 10). Potatoes treated with KSU12800 plus dimethenamid-P had a greater percentage of U.S. No. 1 tubers in the > 339 g category (20%) compared to the standard herbicide treatment (11%) (Table 10). Tuber specific gravity was not significantly affected by herbicide treatment at Paterson and averaged 1.09 (data not shown). Because the study sites were irrigated, moisture availability was discounted as a possible source of any observed variation in weed control and yield.

In summary, pyroxasulfone and saflufenacil controlled common lambsquarters, hairy nightshade, redroot pigweed, and annual grasses to various degrees in these trials without appreciable injury to potato or reduction in potato yield. KSU12800 at 0.15 kg ha$^{-1}$ controlled annual broadleaf weeds well at Ontario with little or no early season visual injury to potatoes. Incomplete broadleaf weed control with KSU12800 at 0.15 kg ha$^{-1}$ at the Paterson site might partially have been due to the herbicide leaching below the zone of emerging weeds on the more sandy, low-organic matter soil. Applied in tank mixtures to broaden the weed control spectrum, these herbicides could be useful in potato production, especially for management of metribuzin-resistant weeds. Further testing of these herbicides under weed-free conditions on additional soil types and potato varieties is needed to ensure crop safety in other situations.

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## Literature Cited

Ackley, J. A., H. P. Wilson, and T. E. Hines. 1996. Efficacy of rimsulfuron and metribuzin in potato (*Solanum tuberosum*). Weed Technol. 10:475–480.

Alvarez, J. M. and P.J.S. Hutchinson. 2005. Managing hairy nightshade to reduce potato viruses and insect vectors. Outlooks Pestic. Manag. J. 16:249–252.

Anonymous. 1991. United States Standards for grades of potatoes. Beltsville, MD: USDA Agricultural Marketing Service. 10 p.

Anonymous. 2005. Pesticide use statistics. National Agricultural Statistics Service. http://www.pestmanagement.info/nass/act_dsp_statcs3_crop.cfm. Accessed: January 2012.

Anonymous. 2006. Sencor 75 DF Herbicide Label. EPA Reg. No. 264–738. Research Triangle Park, NC.: Bayer CropScience. 21 p

Boydston, R. A. 2007. Potato (*Solanum tuberosum*) and weed response to postemergence-applied halosulfuron, rimsulfuron, and EPTC. Weed Tech. 21:465–469.

Boydston, R. A., P. J. S. Hutchinson, and R. R. Bellinder. 2008a. Managing weeds. Pages 223–234 *in* D. A. Johnson, ed. Potato Health Management. St. Paul, MN. APS Press.

Boydston, R. A., H. Mojtahedi, J. M. Crosslin, C. R. Brown, and T. Anderson. 2008b. Effect of hairy nightshade (*Solanum sarrachoides*) presence on potato nematode, disease, and insect pests. Weed Sci. 56:151–154.

Eberlein, C. V., J. C. Witmore, C. E. Stanger, and M. J. Guttieri. 1994. Postemergence weed control in potatoes (*Solanum tuberosum*) with rimsulfuron. Weed Technol. 8:428–435.

Eleftherohorinos, I. G., I. B. Vasilakoglou, and K. V. Dhima. 2000. Metribuzin resistance in *Amaranthus retroflexis* and *Chenopodium album* in Greece. Weed Sci. 48:69–74.

Friesen, G. H. and D. A. Wall. 1984. Response of potato (*Solanum tuberosum*) cultivars to metribuzin. Weed Sci. 32:442–444.

Geier, P. W., P. W. Stahlman, and L. D. Charvat. 2009. Dose responses of five broadleaf weeds to saflufenacil. Weed Technol. 23:313–316.

Grossmann, K., J. Hutzler, G. Casdpar, J. Kwiatkowski, and C. L. Brommer. 2011. Saflufenacil (Kixor™): Biokinetic properties and mechanism of selectivity of a new protoporphrinogen IX oxidase inhibiting herbicide. Weed Sci. 59:290–298.

Heap, I. 2011. International Survey of Herbicide Resistant Weeds. http://www.weedscience.org/In.asp. Accessed: January 2012.

Kadir, S., K. Al-Khatib, R. Boydston, T. Lanini, and T. Miller. 2007. KSU12800: a new herbicide for vineyards and orchards. Proc. West. Soc. Weed Sci. 60:14–15. http://www.wsweedscience.org/Proceedings%20Archive/2007.pdf. Accessed January 2012.

Lyon, D. J. and A. R. Kniss. 2010. Proso millet tolerance to saflufenacil. Weed Technol. 26:349–355.

Moran, M., P. H. Sikkema, and C. J. Swanton. 2011. Efficacy of saflufenacil plus dimethenamid-P for weed control in corn. Weed Technol. 25:330–334.

Nelson, D. C. and M. C. Thoreson. 1981. Competition between potatoes (*Solanum tuberosum*) and weeds. Weed Sci. 29:672–677.

Nurse, R. E., P. H. Sikkema, and D. E. Robinson. 2011. Weed control and sweet maize (*Zea mays* L.) yield as affected by pyroxasulfone dose. Crop Prot. 30:789–793.

Ogg, A. G. and J. H. Dawson. 1984. Time of emergence of eight weed species. Weed Sci. 32:327–335.

Robinson, D. E., N. Soltani, and P. H. Sikkema. 2012. Response of eght sweet maiz (*Zea mays* L.) hybrids to saflufenacil alone or pre-mixed with dimethenamid-P. Amer. J. Plant Sci. 3:96–101.

SAS. 2008. User's Guide, Second Edition. Version 9.2. Cary, NC: SAS Institute, Inc. 266 p.

Sikkema, P. H., D. E. Robinson, R. E. Nurse, and N. Soltani. 2007. Pre-emergence herbicides for potential use in pinto and small red Mexican bean (*Phaseolus vulgaris*) production. Crop Prot. 27:124–129.

Stark, J. C. and S. L. Love, eds. 2003. Potato Production Systems. Moscow, ID: University of Idaho Agricultural Communications. 426 p.

Strand, L. 2006. Integrated Pest Management for Potatoes in the Western United States. 2nd ed. University of California Statewide Integrated Pest Management Program. Publ. 3316. Oakland, CA: Agriculture and Natural Resources Communication Services, University of California. 167 p.

Tanetani, Y., K. Kaku, K. Kawai, T. Fujioka, and T. Shimizu. 2009. Action mechanism of a novel herbicide, pyroxasulfone. Pestic. Biochem. Physiol. 95:47–55.

Vangessel, M. J. and K. A. Renner. 1990. Effect of soil type, hilling time, and weed interference on potato (*Solanum tuberosum*) development and yield. Weed Technol. 4:299–305.

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