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Yellow Nutsedge Control and Reduced Tuber Production with S-metolachlor, Halosulfuron plus Dicamba, and Glyphosate in Furrow Irrigated Corn

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Abstract:	Yellow nutsedge is an important weed problem in the furrow irrigated fields in the Treasure Valley of eastern Oregon and southwestern Idaho. Field studies were conducted in 2008 and 2009 to evaluate the effect of PPI S-metolachlor or EPTC followed by POST halosulfuron and dicamba plus glyphosate or glyphosate alone on foliar yellow nutsedge control and tuber production in corn. Corn plant height at 8 and 24 DAT was reduced 20% and 17%, respectively, in POST herbicides alone compared to PPI plus POST herbicide treatments. Yellow nutsedge control at 8 DAT averaged 78% for treatments that included PPI application of EPTC or S-metolachlor 1,600 g ai ha-1 followed by halosulfuron plus dicamba (35 plus 155 g ha-1 or 70 plus 310 g ha-1) plus glyphosate 785 g ha-1 compared to POST treatments alone (49%). The control at 24 DAT was 84% for treatments that contained halosulfuron plus dicamba compared to 73% for POST glyphosate alone. Yellow nutsedge tubers were reduced 56 to 68% among treatments at the end of 2008. Tuber reduction in 2009 was greater with treatments that included PPI herbicides followed by sequential halosulfuron plus dicamba (35 plus 155 g ha-1) plus glyphosate compared to glyphosate alone. Corn yield reflected the level of yellow nutsedge control and early season weed interference. Treatments that included PPI herbicides had an average yield of 8.2 T ha-1 compared to 6.6 T ha-1 with sequential glyphosate alone. There was a correlation between percent foliar control and the number of yellow nutsedge tubers produced at the end of each year. Application of PPI herbicides followed by POST halosulfuron plus dicamba (35 plus 155 g ha-1 or 70 plus 155 g ha-1) plus glyphosate improved yellow nutsedge control, reduced early corn/weed competition, and produced the highest corn yield under furrow irrigated conditions.

Yellow Nutsedge Control and Reduced Tuber Production with *S*-metolachlor, Halosulfuron plus Dicamba, and Glyphosate in Furrow Irrigated Corn

Felix and Newberry: Yellow nutsedge control in corn with halosulfuron

Joel Felix and George Newberry*

Yellow nutsedge is an important weed problem in the furrow irrigated fields in the Treasure Valley of eastern Oregon and southwestern Idaho. Field studies were conducted in 2008 and 2009 to evaluate the effect of PPI *S*-metolachlor or EPTC followed by POST halosulfuron and dicamba plus glyphosate or glyphosate alone on foliar yellow nutsedge control and tuber production in corn. Corn plant height at 8 and 24 DAT was reduced 20% and 17%, respectively, in POST herbicides alone compared to PPI plus POST herbicide treatments. Yellow nutsedge control at 8 DAT averaged 78% for treatments that included PPI application of EPTC or *S*-metolachlor 1,600 g ai ha^{-1} followed by halosulfuron plus dicamba (35 plus 155 g ha^{-1} or 70 plus 310 g ha^{-1}) plus glyphosate 785 g ha^{-1} compared to POST treatments alone (49%). The control at 24 DAT was 84% for treatments that contained halosulfuron plus dicamba compared to 73% for POST glyphosate alone. Yellow nutsedge tubers were reduced 56 to 68% among treatments at the end of 2008. Tuber reduction in 2009 was greater with treatments that included PPI herbicides followed by sequential halosulfuron plus dicamba (35 plus 155 g ha^{-1}) plus glyphosate compared to glyphosate alone. Corn yield reflected the level of yellow

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Nomenclature: EPTC; dicamba; glyphosate; halosulfuron; *S*-metolachlor; yellow nutsedge, *Cyperus esculentus* L.; Corn, *Zea mays* L., 'DK C52-59-RR'.

Key words: furrow irrigation, yellow nutsedge control, halosulfuron, tuber reduction.

Yellow nutsedge is a troublesome weed worldwide and has been designated a prohibited noxious weed in 10 states in the US (Anderson 1999). Control of yellow nutsedge is difficult because reproduction is mainly by underground vegetative propagules (rhizomes and tubers), which persist for 3 to 5 yr (DeFelice 2002). The tubers are produced on rhizomes and consist of a rhizomatous tissue with numerous buds (Akin and Shaw 2001; Stoller 1975), which makes yellow nutsedge capable of resprouting if the original shoot is removed or injured. The buds sprout under favorable weather conditions and initiate rhizomatous growth which develops into shoots, and eventually grow into mature plants and become an effective means of spread in infested fields (Holm et al. 1977). The persistence of yellow nutsedge in agricultural fields is influenced by crop production practices and rotation schemes. Field preparation and mechanical weed management activities also play a significant role in horizontal yellow nutsedge distribution in infested fields (Schippers et al. 1993; Webster 2005). Even though yellow nutsedge is adapted to different field conditions, it flourishes under furrow irrigated conditions because of the abundance of moisture throughout the season.

Yellow nutsedge is an important weed problem of agricultural fields in the Treasure Valley of eastern Oregon and southwestern Idaho. The proliferation in the area is mainly due to lack of effective control strategies in direct-seeded dry bulb onion (*Allium cepa* L.), a major rotational crop in the region. Field beds in the Treasure Valley are designed to facilitate furrow irrigation and are formed during the fall preceding spring onion planting. Furthermore, the equipments used to create a uniform gradient and furrow irrigation beds possibly contribute to the distribution of yellow nutsedge in the fields. Surveys conducted by Ransom et al. (2003) indicated an average of 42 percent dry bulb onion yield reduction in fields that were heavily infested with yellow nutsedge. Thus, development of effective yellow nutsedge control strategies is necessary for sustainability of the local onion industry. Research results at the Malheur Experiment Station have indicated that millions of tubers ha^{-1} are produced each season in heavily infested fields (Felix et al. 2007; Shock et al. 2006). Because tubers play an important role in the propagation of yellow nutsedge, long term control could be achieved by reducing the population density of viable tubers, thus resulting in long-term control (Akin and Shaw 2001). Therefore, successful control of yellow nutsedge in the Treasure Valley will partly require development of diverse crop rotations that include corn, because it has a wider array of registered effective herbicides to control and reduce tubers in the years preceding onion. Because furrow irrigation encourages extended germination of yellow nutsedge, POST herbicides preceded by soil residual products like *S*-metolachlor, may provide increased control in glyphosate resistant corn during the years preceding onion.

The premix of halosulfuron-methyl and the sodium salt of dicamba provides selective control of some annual broadleaf weeds and yellow nutsedge in corn (Anonymous 2003; Fischer and Harvey 2002; Molin et al. 1997). Different performances of sulfonylurea herbicides mixed with dicamba have been reported. Damalas and Eleftherohorinos (2001) reported dicamba antagonism with primisulfuron, whereas Franetovich and Peeper (1995) and Ngouajio and Hagood (1993) reported improved weed control. The design of our treatments did not allow any inferences on dicamba influence on yellow nutsedge control in this study. Halosulfuron is a sulfonylurea herbicide that inhibits acetolactate synthase, an enzyme involved in the synthesis of branched-chain amino acids isoleucine, leucine, and valine in plants (Senseman 2007). The herbicide is readily absorbed by plant roots and foliage and translocated throughout the plant, causing rapid growth inhibition in susceptible plants. Several researchers have reported yellow nutsedge control with halosulfuron under rainfed conditions (Fischer and Harvey 2002; Nelson and Renner 2002; Sprankle et al. 1992; Thomas et al. 2004a, 2004b; Vencill et al. 1995), but information on performance under furrow irrigated systems is lacking. Hahn (1997) reported similar yellow nutsedge control with halosulfuron applied to 9 or 18 cm-tall plants. When applied to 9 cm-tall yellow nutsedge, halosulfuron at 53 g ha^{-1} resulted in 90 to 97% foliar control. Johnson and Mullinix (1996) found that halosulfuron applied at 18, 36, or 72 g ha^{-1} controlled yellow nutsedge more effectively than bentazon. Ackley et al. (1996) reported that halosulfuron provided at least 88% yellow nutsedge control and the surviving plants were noncompetitive. Most of these studies reported foliar yellow nutsedge control but provided no information on the level of tuber production.

With the introduction of glyphosate resistant crops, growers are able to apply glyphosate over the crop to control weeds. Glyphosate plus halosulfuron POST provided effective yellow nutsedge control than glyphosate POST alone in 10 of 12 comparisons (Thomas et al. 2004a). *S*-metolachlor is extensively used and was applied on 23% of the corn hectares in the US in 2005 for PRE control of grasses, broadleaf weeds, and sedges (USDA 2005). The complementary effects of PPI and POST herbicides might improve yellow nutsedge control in furrow irrigated systems. The objective of this study was to evaluate yellow nutsedge foliar control and tuber production with PPI herbicides and POST halosulfuron plus dicamba plus glyphosate applications compared to glyphosate alone under furrow irrigation conditions.

Materials and Methods

Field studies were conducted in 2008 and 2009 in grower fields near Fruitland, ID (44 01 36.59 N, -116 55 08.39 W) and Ontario, OR (44 08 08.13 N, -116 55 26.90 W), respectively, to determine yellow nutsedge control and tuber production with PPI herbicides and POST halosulfuron plus glyphosate or glyphosate alone in corn under furrow irrigated conditions. Halosulfuron was applied as a prepackaged mixture with dicamba, which likely improved broadleaf control. Each study was conducted in a well-drained, furrow-irrigated field, which had been planted to wheat the previous year. The predominant soil at the 2008 site was a Clems fine sandy loam (Coarse-loamy, mixed, superactive, mesic Xeric Haplocambids with 67%, 20%, and 13% sand, silt, clay, respectively), a pH of 6.8, 1.1% organic matter, and a CEC of 9 meq 100g^{-1} soil. The soil at the 2009 site was an Owyhee silt loam (Coarse-silty, mixed, superactive, mesic Xeric Haplocambids with 14%, 72%, and 14% sand, silt, and clay, respectively), a pH 7.9, 1.29% organic matter and a CEC of 14 meq 100 g^{-1}. The fields were moldboard plowed during fall of the preceding year and were disked, roller harrowed and beds formed at 75 cm spacing on May 8, 2008 and May 9, 2009. Herbicide treatments were arranged in randomized complete block design with four replications. Individual plots were 3 m wide (four rows) and 9 m in length. Herbicide application dates are presented in Table 1. An untreated control was also included.

The PPI treatments were applied May 19, 2008 and May 20, 2009 and a Lilliston rolling cultivator (Lilliston Corporation, Albany, GA) used to incorporate the herbicides to a 10 cm soil depth. John Deere planter model 71 flexi (Deere & Company, Moline IL) was used to plant Roundup Ready® corn hybrid 'DK C52-59-RR' on May 22, 2008 and May 20, 2009 with seeds spaced 20 cm within the row. The field was fertilized according to soil test and other corn production operations followed standard local practices. The studies were furrow irrigated 12 times during each growing season, and each irrigation occurrence lasted 24 h to deliver approximately 10 cm of water. All herbicide treatments were applied using a CO_2 pressurized backpack sprayer (Bellspray Inc., R&D Sprayers, Opelousas, LA) with a boom fitted with six 8002 EVS TeeJet nozzles (Spraying Systems Co., Wheaton, IL) calibrated to deliver 187 L ha^{-1} at 241 kPa and 4.8 kmh. Plots were visually evaluated for crop injury and weed control based on a 0 to 100 percent scale (where 0 percent = no crop injury or no weed control and 100 percent =

complete crop kill or complete weed control) at 8, 24, and 42 d after POST herbicide application. Corn was harvested by hand-picking the ears at maturity on October 17, 2008 and October 30, 2009 from 6 m of the two center rows in each plot and shelled to determine yield. John Deere portable grain moisture tester model TY9304 (John Deere Ltd., Grimsby, Ontario, Canada) was used to determine corn grain moisture. The final corn grain yield was adjusted to 15.5% moisture.

The population densities of yellow nutsedge tubers in each plot were quantified before and after the treatments were imposed. Five soil cores (30 cm depth each) were randomly collected from each plot using a soil probe measuring 10.8 cm diameter on April 29, 2008 and May 1, 2009 to quantify yellow nutsedge tubers. The same number of samples was drawn on October 6, 2008 and October 15, 2009 to estimate the change in yellow nutsedge tuber population density in response to herbicide treatments. The five soil samples from each plot were combined, and processed using a wash and sieving method to recover yellow nutsedge tubers. The soil was placed in a 50 L metal container filled with 20 L of water and stirred using an electric powered flat end auger until all the soil clods were completely pulverized. The mixture was poured through two stacked sieves with mesh size openings of 1.27 cm and 0.198 cm. The two sieves were placed inside a metallic container (61 cm wide by 64 cm length by 30 cm depth) that had a 0.15 cm sieve openings at the bottom. A hand held hose was used to wash the soil mixture through the sieves. The tubers were separated by hand from root fragments and other debris, placed in a ziplock bag, and stored in refrigerated storage (4 C) until they were enumerated and weighed. Tuber viability was tested by applying light pressure during counting, and all firm tubers were considered viable.

Data were subjected to a normality test by plotting the residuals. Because analysis of square-root transformed data did not change the results of ANOVA, the nontransformed data were used in the final analysis. The data were subjected to ANOVA using PROC GLM procedure in SAS (Version 9.2. SAS Institute, Inc., Cary, NC; SAS 2008). Type III statistics were used to test for significant differences ($P \leq 0.05$) between site years, herbicide treatments and their interactions for corn plant height, yellow nutsedge control, number of yellow nutsedge tubers, percent change in tubers population density and corn yield. Data were pooled between sites when no significant site year or site year by treatment interactions were detected. Mean separations were performed using Fisher's protected LSD test at a $P \leq 0.05$. The linear regression procedure in SigmaPlot (Systat Software, Inc., San Jose, CA) was used to determine the relationship between percent control assessments and the number of tubers produced at the end of the season. ANOVA indicated no differences between site years or interactions with herbicide treatments for corn plant height and yellow nutsedge control at 8, 24, and 42 DAT, so data for each variable were pooled between site years and analyzed for herbicide treatment effects. Because ANOVA indicated similar results for evaluations at 24 and 42 DAT, only evaluations at 24 DAT are presented. The number of yellow nutsedge tubers m^{-2} before and after herbicide application varied by site year and the results are presented separately. Corn yield in response to different herbicide rates was similar between site years and was pooled for analysis to determined treatment effects.

Results and Discussion

Corn plant height. Corn plant height varied among herbicide treatments 8 DAT (Table 2). Corn plants in plots treated with PPI application of EPTC or *S*-metolachlor averaged 41 cm in height compared to 33 cm for POST tank-mixtures of halosulfuron 35 or 70 g ha^{-1} plus glyphosate 785 g ha^{-1} or glyphosate alone at 785 g ha^{-1}. Differences in corn plant height were still apparent among herbicide treatments at 24 DAT, but had slightly subsided possibly in response to fertilizer application. Plant height at 24 DAT in the plots that received PPI application of EPTC or *S*-metolachlor followed by POST herbicide applications averaged 64 cm compared to 54 cm for POST only herbicide treatments. Corn plant height in the untreated plots was 31 and 35 cm at 8 and 24 DAT, respectively. These results indicated that corn plant growth at 8 DAT was reduced an average of 19% for POST alone treatments and 24% for the untreated control, compared to PPI herbicides plus POST treatments. The corresponding reduction in plant height at 24 DAT was 16 and 45%, respectively. Early weed competition reduced corn growth and grain yield in other studies (Bosnic and Swanton 1997; Hall et al. 1992; Massinga et al. 2001; Thomas et al. 2004b). Yellow nutsedge seems to respond to high soil moisture under furrow irrigated conditions compared to slower corn growth early in the season, and the use of PPI herbicides improved early corn growth by minimizing the weed competition.

Yellow nutsedge control at 8 DAT averaged 78% in plots that received PPI application of EPTC or *S*-metolachlor followed by POST applications compared to an average of 49% with POST only treatments (Table 2). The use of PPI herbicides improved yellow nutsedge control at 8 DAT by 37% compared to POST alone treatments. Evaluations at 24 DAT indicated lower yellow nutsedge control in plots that received sequential POST glyphosate (73%) compared to the PPI applications of EPTC or *S*-metolachlor followed by a mixture of halosulfuron plus dicamba 35 plus 155 or 70 plus 310 g ha^{-1} plus glyphosate POST (86%). Estimated yellow nutsedge control at 24 DAT was similar for treatments that included PPI plus POST and the sequential POST application of halosulfuron plus dicamba 35 plus 155 g ha^{-1} plus glyphosate. There was no discernible yellow nutsedge growth reduction from corn shading in the untreated control plots. These results indicated that the use of PPI application of EPTC or *S*-metolachlor followed by halosulfuron plus dicamba (35 plus 155 or 70 plus 310 g ha^{-1}) plus POST glyphosate or sequential application of halosulfuron plus dicamba 35 plus 155 g ha^{-1} plus glyphosate improved yellow nutsedge control 14% compared to sequential POST glyphosate alone. Improved yellow nutsedge control with PRE *S*-metolachlor and EPTC under rainfed conditions has been reported (Burke et al. 2008; Loux et al. 2011; Obrigawitch et al. 1980; Stephenson IV 2004). Furthermore, these results corroborate research findings on yellow nutsedge control under rainfed conditions at similar halosulfuron application rates. Vencill et al. (1995) reported reduced yellow nutsedge shoot dry weight 60 DAT when halosulfuron was applied POST at 53 g ha^{-1}. Sprankle et al. (1992) observed improved yellow nutsedge control with halosulfuron applied at 73 to 94 g ha^{-1} compared to acetochlor, alachlor, butylate, and metolachlor. On the other hand, Thomas et al. (2004a) reported 94% yellow nutsedge control with sequential POST application of glyphosate in corn under rainfed conditions. In our studies under furrow irrigated conditions, yellow nutsedge control with sequential glyphosate application was 73%. The greater yellow nutsedge control observed by Thomas et al. (2004a) might have been associated with the higher glyphosate rate used (1,120 g ha^{-1}) compared to 785 g ha^{-1} in our studies. However, incomplete yellow nutsedge control under furrow irrigated conditions may also be associated with constant moisture availability that enables plants to recover or produce new shoots, particularly within the irrigation furrow.

Yellow nutsedge and broadleaf control. Control for common lambsquarters (*Chenopdium album*), redroot pigweed (*Amaranthus retroflexus*), barnyardgrass (*Echinichloa crus-galli*), and large crabgrass (*Digitaria sanguinalis*) at 8 and 24 DAT was 99% among herbicide treatments (data not shown). All herbicide treatments provided season long control of the above weed species (data not shown). Season long broadleaf weed control with halosulfuron plus glyphosate or glyphosate alone has been reported (Ackley 1996; Ferrell and Witt 2002; Thomas et al. 2004a, 2004b). Dicamba was applied as a component of the premix product (Yukon®) that contained halosulfuron and likely improved the broadleaf control in these studies. Other researchers have reported improved weed and volunteer crops control in corn with dicamba (Boydston 2004; Franssesn and Kells 2007; Kalnay and Glenn 2000; Nurse et al. 2007).

Soil samples taken at the beginning of the 2008 study indicated similar number of yellow nutsedge tubers among herbicide treatments that ranged from 2,230 to 2,924 m^{-2} (Table 3). Soil samples taken in October 2008 indicated that all herbicide treatments reduced the number of tubers compared to the untreated control. The number of tubers at the end of the 2008 study ranged from 837 to 1,301 m^{-2} among herbicide treatments, while tubers in the untreated control increased from 2,460 to 3,094 m^{-2}. The change in yellow nutsedge tubers at the end of the 2008 cropping season reflected a 25% increase for the untreated control compared to a decrease of 56 to 68% among herbicide treatments. Yellow nutsedge tubers at the beginning of the 2009 study ranged from 427 to 1,427 m^{-2} among herbicide treatments. The soil sampled at the end of the season indicated a 55% increase in the number of tubers in the untreated control. The number of tubers at the end of 2009 was 312 and 335 m^{-2} for treatments that included PPI herbicides compared to 366 m^{-2} for sequential POST glyphosate alone. Tubers in plots treated with POST halosulfuron plus dicamba (35 plus 155 g ha^{-1} or 70 plus 310 g ha^{-1}) mixed with glyphosate ranged from 213 to 241 m^{-2}. The greatest yellow nutsedge tuber reduction (-80%) in 2009 was observed with the sequential POST application of halosulfuron plus dicamba (35 plus 155 g ha^{-1}) plus glyphosate, which was similar to the PPI application of EPTC or *S*-metolachlor followed by a POST tank-mixture of halosulfuron plus dicamba (35 plus 155 g ha^{-1} or 70 plus 310 g ha^{-1}) plus glyphosate (-56 and -75%, respectively). The lowest yellow nutsedge tuber decrease in 2009 ranged from -26 to -48% and were associated with the POST application of the tank-mixture of halosulfuron plus dicamba (35 plus 155 g ha^{-1} or 70 plus 310 g ha^{-1}) plus glyphosate or sequential POST application of glyphosate alone.

These results suggested improved yellow nutsedge control and reduced tuber production with the PPI application of *S*-metolachlor 1,600 g ha^{-1} followed by the POST tankmix of halosulfuron 35 or 70 g ha^{-1} plus glyphosate 785 g ha^{-1} compared to one-pass POST programs. Also, sequential POST application of halosulfuron at 35 g ha^{-1} tankmixed with glyphosate 785 g ha^{-1} was more effective in yellow nutsedge control compared to sequential POST application of glyphosate 785 g ha^{-1} alone. The convenience of a single POST application of halosulfuron 70 g ha^{-1} plus glyphosate 785 g ha^{-1} may be preferred by growers compared to sequential halosulfuron 35 g ha^{-1} mixed with glyphosate 785 g ha^{-1}. However, the single POST application was not as effective in reducing tuber numbers as the sequential application of PPI *S*-metolachlor followed by POST halosulfuron. Importantly, the PPI herbicide treatment may be required to minimize early season weed-crop competition.

These results for yellow nutsedge control in furrow irrigated systems are similar to those reported by Fischer and Harvey (2002) under rainfed conditions. Also, our results indicated that yellow nutsedge tuber reduction with halosulfuron plus dicamba and glyphosate under furrow irrigated corn production were similar to those reported under greenhouse or rainfed conditions (Vencill 1995; Webster and Coble 1997; Molin 1999). It has been reported that the half-life for halosulfuron ranges from 6 to 98 d, depending on soil moisture and temperature regimes (Dermiyati and Yamamoto 1997b; Grey et al. 2007). Halosulfuron degradation is accelerated by high temperature and low soil pH, with soil type and moisture content further influencing the dissipation (Dermiyati and Yamamoto 1997a; Dermiyati and Yamamoto 1997b). The 2008 and 2009 sites had a soil pH of 6.8 and 7.9 with an organic matter of 1.1 and 1.29%, respectively. Halosulfuron sorption and desorption would occur at this pH level resulting in extended yellow nutsedge control, which is accompanied by reduced tuber production.

Corn yield. The corn grain yield reflected early season weed interference and the level of yellow nutsedge control among herbicide treatments (Table 3). The highest average yield of 8.2 T ha^{-1} was obtained from treatments that included PPI herbicides followed by POST application of halosulfuron plus dicamba (regardless of the rate) plus glyphosate. Corn yield for total POST programs that included halosulfuron plus dicamba (35 plus 155 g ha^{-1} or 70 plus 310 g ha^{-1}) plus glyphosate was reduced by 7% compared to treatments that included PPI herbicides. Application of sequential POST glyphosate alone reduced corn yield by 20% compared to the application of PPI herbicides followed by POST halosulfuron. Gower et al. (2003) reported that in the absence of a PRE herbicide application, delaying the POST glyphosate application to allow greater numbers of weeds to emerge led to a decrease in corn grain yield due to weed competition. Our results corroborate the finding by Gower et al. (2003) and further indicate that early season weed interference and the level of yellow nutsedge control affects corn yield under furrow irrigation practices. Reduced corn yield because of early weed competition for total POST glyphosate was reported recently by Parker et al. (2007).

Linear regression analysis indicated a strong relationship (R^2=0.94 and P=0.0003) between percent control assessment at 24 DAT and the number of yellow nutsedge tubers produced at the end of the season (Figure 1). These results suggest that deliberate control assessments could be used to accurately predict the level of yellow nutsedge tuber production in response to herbicide treatments. This is especially reassuring given that soil sampling and the methods used to retrieve and quantify the tubers are very tedious and are not likely to be done by many weed managers.

The results from these studies indicated that yellow nutsedge control in furrow irrigated systems with treatments that included halosulfuron was similar to previous findings under rainfed conditions. Yellow Nutsedge control and consequently grain yields were improved in treatments that included both PPI and POST treatments, but not different from sequential POST halosulfuron plus glyphosate. Application of the PPI herbicides reduced early-season weed competition by reducing the number of weeds that emerged with the crop. Additionally, the use of PPI herbicides in corn production under furrow irrigation may allow growers to delay the POST herbicide application and possibly eliminate the need for a second POST application. Furthermore, the concomitant reduction in tuber production might contribute positively to the reduction of yellow nutsedge pressure in the successive crops grown in a rotation.

As growers develop rotations that include corn, it is important to remember that onion sensitivity to halosulfuron soil residues will necessitate planting of other crops (e.g. dry beans (*Phaseolus vulgaris*), potato (*Solanum tuberosum*) or wheat (*Triticum aestivum*)) before rotating to onions. The halosulfuron label suggests 18 and 24 mo before planting onion and sugar beet, respectively (Anonymous 2003). The use of PPI herbicides should be part of a diversified yellow nutsedge control program in light of the increasing prevalence of glyphosate-resistant weed species in the US.

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Table 1. Herbicide treatments tested to control yellow nutsedge and tuber production at Fruitland, ID and Ontario, OR in 2008 and 2009, respectively.

		Application	Application date	
Treatment[a]	Rate	Timing[b]	2008	2009
Untreated check	g ai or ae ha^{-1}			
EPTC[c] or *S*-metolachlor	1,600	PPI	5/19	5/20
Halosulfuron-methyl + dicamba +	35 + 155	POST	6/24	6/22
Glyphosate	785			
EPTC or *S*-metolachlor	1,600	PPI	5/19	5/20
Halosulfuron-methyl + dicamba +	70 + 310	POST	6/24	6/22
Glyphosate	785			
Halosulfuron-methyl + dicamba +	35 + 155	POST	6/24	6/22
Glyphosate	785			
Halosulfuron-methyl + dicamba +	70 + 310	POST	6/24	6/22
Glyphosate	785			
Halosulfuron-methyl + dicamba +	35 + 155	EPOST	6/18	6/22
Glyphosate	785			
Halosulfuron-methyl + dicamba +	35 + 155	7 d after EPOST	6/24	6/28
Glyphosate	785			
Glyphosate	785	POST	6/24	6/22
Glyphosate	785	POST	7/10	6/28

[a] Halosulfuron plus dicamba plus glyphosate treatments included ammonium sulfate and nonionic surfactant at 2.5 and 0.25% v/v, respectively, and ammonium sulfate 2.5% v/v for glyphosate alone.

[b] Abbreviations: PPI, Pre-plant incorporated; EPOST, Early post emergence; POST, post emergence.

[c] EPTC was replaced by *S*-metolachlor in 2009 because the formulation used in 2008 (Eradicane®) was withdrawn from the market.

Table 2. Corn growth reduction and yellow nutsedge control assessments at 8 and 24 days after herbicide application at Fruitland, ID and Ontario, OR in 2008 and 2009, respectively.

			Corn Height[c]		Yellow nutsedge Control[c]	
Treatment[a]	Rate	Application Timing [b]	8 DAT	24 DAT	8 DAT	24 DAT
	g ai or ae ha^{-1}		------------- cm --------------		---------------- % -----------------	
Untreated check			31 c	35 c	0 c	0 c
EPTC[d] or *S*-metolachlor	1,600	PPI	40 a	64 a	81 a	86 a
Halosulfuron-methyl + dicamba +	35 + 155	POST				
Glyphosate	785					
EPTC or *S*-metolachlor	1,600	PPI	41 a	64 a	75 a	86 a
Halosulfuron-methyl + dicamba +	70 + 310	POST				
Glyphosate	785					
Halosulfuron-methyl + dicamba +	35 + 155	POST	33 b	53 b	53 b	81 ab
Glyphosate	785					
Halosulfuron-methyl + dicamba +	70 + 310	POST	33 b	53 b	49 b	79 ab
Glyphosate	785					
Halosulfuron-methyl + dicamba +	35 + 155	EPOST	33 b	54 b	48 b	87 a
Glyphosate	785					
Halosulfuron-methyl + dicamba +	35 + 155	7 d after EPOST				
Glyphosate	785					
Glyphosate	785	POST	32 b	54 b	46 b	73 b
Glyphosate	785	POST				

[a] Halosulfuron plus dicamba plus glyphosate treatments included ammonium sulfate and nonionic surfactant at 2.5 and 0.25% v/v, respectively, and ammonium sulfate 2.5% v/v for glyphosate alone.

[b] Abbreviations: PPI, Pre-plant incorporated; EPOST, Early post emergence; POST, post emergence.

[c] Means within a column followed by the same letter are not significantly different according to LSD (*P*=0.05).

[d] EPTC was used in 2008 and replaced by *S*-metolachlor in 2009 because the formulation (Eradicane®) was withdrawn from the market.

Table 3. Yellow nutsedge tuber population density before and after herbicide application and corn yield at Fruitland, ID and Ontario, OR in 2008 and 2009, respectively.

			2008 Tubers[c]			2009 Tubers			Corn
Treatment[a]	Rate	Application timing [b]	Before	After	change[e]	Before	After	change[e]	yield
	g ai or ae ha^{-1}		----- No. m^{-2} -------		--- % ----	----- No. m^{-2} -------		---- % ----	T ha^{-1}
Untreated check			2,460 a	3,094 a	25 a	895 a	1387 c	55 a	3.2 d
EPTC[d] or *S*-metolachlor	1,600	PPI	2,695 a	864 b	-68 b	809 b	335 a	-56 b	8.4 a
Halosulfuron-methyl + dicamba +	35 + 155	POST							
Glyphosate	785								
EPTC[d] or *S*-metolachlor	1,600	PPI	2,230 a	837 b	-63 b	1427 a	312 a	-75 b	7.9 ab
Halosulfuron-methyl + dicamba +	70 + 310	POST							
Glyphosate	785								
Halosulfuron-methyl + dicamba +	35 + 155	POST	2,793 a	1,028 b	-63 b	427 b	213 b	-26 c	7.4 bc
Glyphosate	785								
Halosulfuron-methyl + dicamba	70 + 310	POST	2,793 a	1,300 b	-56 b	519 b	230 b	-48 c	6.9 c
Glyphosate	785								
Halosulfuron-methyl + dicamba +	35 + 155	EPOST	2,924 a	1,301 b	-56 b	684 b	241 b	-80 b	7.4 bc
Glyphosate	785								
Halosulfuron-methyl + dicamba +	35 + 155	7 d after EPOST							
Glyphosate	785								
Glyphosate	785	POST	2,913 a	1,093 b	-62 b	656 b	366 a	-39 c	6.6 c
Glyphosate	785	POST							

[a] Halosulfuron plus dicamba plus glyphosate treatments included ammonium sulfate and nonionic surfactant at 2.5 and 0.25% v/v, respectively, and ammonium sulfate for glyphosate.

[b] Abbreviations: PPI, Pre-plant incorporated; EPOST, Early post emergence; POST, post emergence.

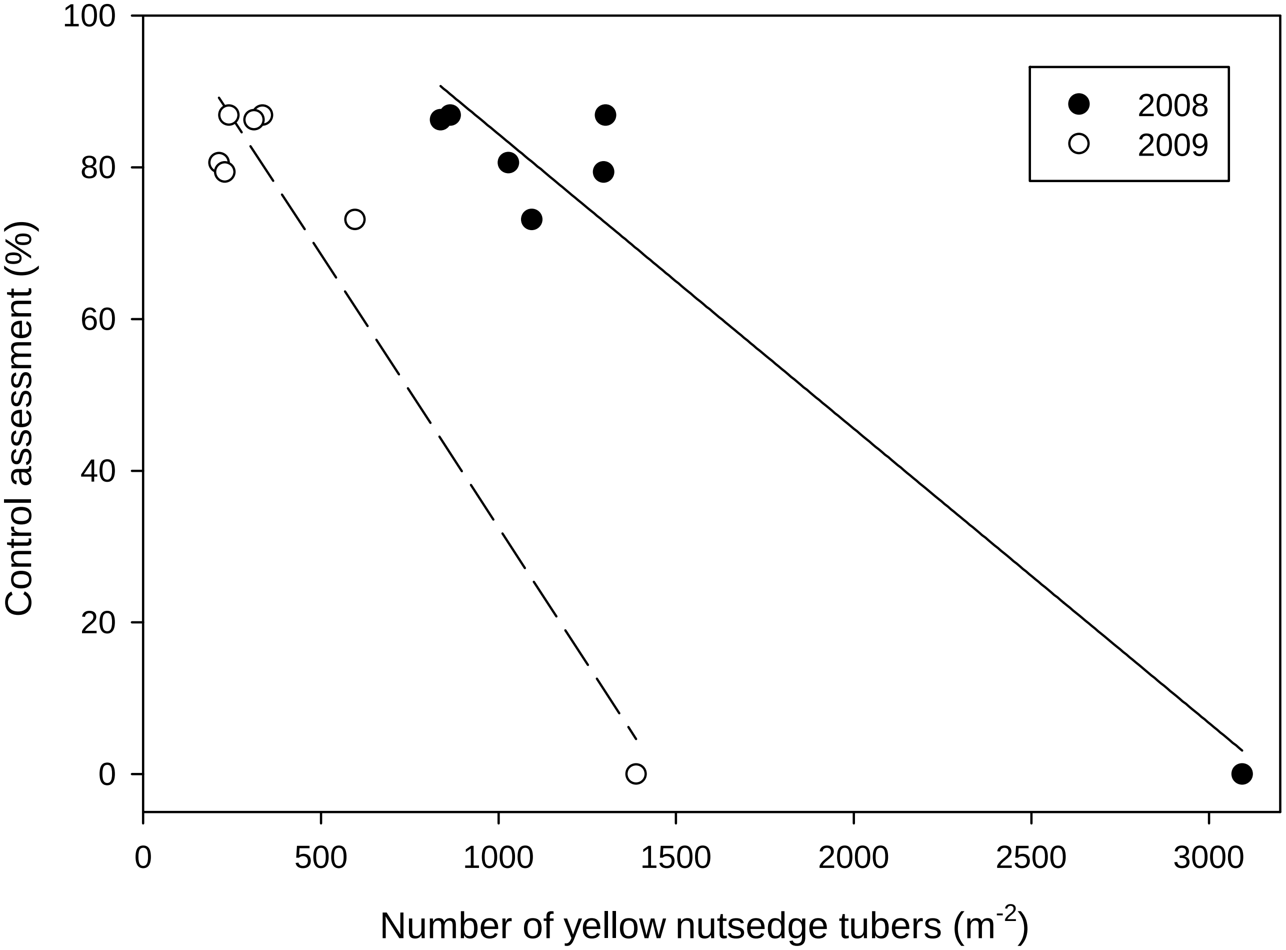
[c] Means within a column followed by the same letter are not significantly different according to LSD P=0.05

[d] EPTC was used in 2008 and replaced by *S*-metolachlor in 2009 because the formulation (Eradicane®) was withdrawn from the market.

[e] Percent tuber change was calculated as (final tuber count – initial tuber count)/initial tuber count*100

Figure caption.

Figure 1. The relationship between yellow nutsedge percent injury at 24 DAT and the number of yellow nutsedge tubers produced at the end of the season at Fruitland, ID and Ontario, OR in 2008 and 2009. Y=123 – 0.0388X; R^2 = 0.94 (2008) and Y=105-0.04X; R^2 = 0.94 (2009).


100
80
60
40
20
0
Control assessment (%)
0
500
1000
1500
2000
2500
3000
Number of yellow nutsedge tubers (m^{-2})
● 2008
○ 2009