DOSE RESPONSE OF ACTIVATED CHARCOAL TO DETOXIFY DUAL MAGNUM® AND OUTLOOK® APPLIED PREEMERGENCE ON DIRECT-SEEDED ONIONS

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Introduction

Yellow nutsedge is a problem in onion fields in the Treasure Valley of eastern Oregon and southwestern Idaho. Dual Magnum® (*S*-metolachlor) and Outlook® (dimethenamid-p) are registered for yellow nutsedge control in onions. However, the application timing of Dual Magnum and Outlook (starting when onions are at the two-leaf stage) makes these herbicides less effective, because Dual Magnum and Outlook are more effective in controlling yellow nutsedge and other weeds when applied prior to their emergence. The potential to use activated carbon to neutralize Dual Magnum and Outlook within the onion row was demonstrated in previous studies (Felix and Ishida 2009, Felix et al. 2010). Determination of the most effective rate for activated carbon to provide adequate crop protection is required in order to determine the cost effectiveness of the practice in direct-seeded onion productions. The objective of this study was to determine the optimum rate of activated carbon to neutralize the herbicides Dual Magnum and Outlook over the onion row when the herbicides are applied prior to onion emergence. **Dual Magnum and Outlook herbicides are not currently registered for preemergence application on direct-seeded dry bulb onions. Always read herbicide labels to ensure that the product is registered for the intended use.**

Materials and Methods

A field study was conducted in 2011 at the Malheur Experiment Station, Ontario, Oregon to determine the dose response of activated charcoal to detoxify Dual Magnum and Outlook applied prior to the emergence of direct-seeded onion. The wheat stubble was flailed and the field plowed during fall 2010. Enough fertilizer to provide 44, 210, 210, 5, 8, and 5 lb/acre of nitrogen, phosphate, sulfur, zinc, and manganese was applied during fall 2010. The field was later groundhogged and 22-inch-wide beds formed. The beds were harrowed and reshaped on April 5, 2011. On April 12, onion variety ‘Vaquero’ was planted and charcoal applied in a single pass. The study followed a split-plot design with simulated rain (with and without) forming the main blocks into which herbicides and charcoal rates were imposed as subplots. The study had three replications and the plots were 7.33 ft wide (4 beds) by 25-ft length. Lorsban® 15G insecticide was applied at 3.7 oz/1,000 ft of row (chlorpyrifos at 0.101 lb ai/acre) on April 18 as a preventive measure against onion maggot.

The activated charcoal used was GRO-SAFE® (Norit Americas Inc., Atlanta, GA) and was applied using a modified planter fitted with a 25-gal Rear's NIFTY Tank Series (Rear's Manufacturing Co., Eugene, OR) with a 1-inch band of activated charcoal slurry sprayed directly over each row. Activated charcoal was applied at the rates of 5, 10, 20, and 25 lb/acre in 50 gal of water on the soil surface directly behind the press wheel of the onion planter.

Dual Magnum was applied at a rate of 1.33 pt/acre (*S*-metolachlor at 1.27 lb ai/acre) and Outlook at 21 fl oz/acre (dimethenamid-p at 0.98 lb ai/acre). The study also included a grower standard, which was treated with Prowl® H2O at 2 pt/acre (pendimethalin at1 lb ai/acre) before onion emergence on May 3. Sprinkler irrigation was applied to half of the plots on May 2, simulating 0.5 inches of rainfall in one hour. The complete list of herbicides and charcoal rates evaluated in 2011 is presented in Table 1.

Onion plants were counted in the center two rows of each plot on May 22 to determine the plant population density in response to herbicide treatments. Poast® at 1.5 pt/acre (sethoxydim at 0.287 lb ai/acre) tank-mixed with crop oil at 2 pt/acre was applied on May 25 to control grassy weeds. Fertilizer was side dressed on June 21 to provide 225 lb nitrogen/acre.

The plants were sprayed four times with different insecticides during the season to control onion thrips. Movento® at 5 fl oz/acre (spirotetramat at 0.078 lb ai/acre) tank-mixed with Pierce (crop oil concentrate) at 1.57 lb ai/acre was applied on June 13. Onions were sprayed again for thrips control on June 22 and July 5 using Radiant® at 10 fl oz/acre (spinetoram at 0.078 lb ai/acre) tank-mixed with crop oil at 1 qt/100 gal of water. The final spray for thrips control was on July 24 using Lannate® at 3 pt/acre (methomyl atl 0.9 lb ai/acre). Furrow irrigation began on May 9 and was regularly applied to maintain proper moisture levels in the top 12 inches of soil profile.

Plant tops were flailed on September 8 and onions were lifted on September 12 and left on the ground to cure. Bulbs were handpicked from 15 ft of the center 2 rows on September 15 and stored in the barn until they were graded. Dry bulb onions were graded on September 25 using USDA standard categories. The data collected were subjected to analysis of variance and means were compared using LSD at $P = 0.05$.

Results and Discussion

There was no significant reduction in plant stand in response to the various rates of activated charcoal when Dual Magnum and Outlook were applied prior to onion emergence (Table 1). Generally, the onion yield results did not indicate significant differences among treatments for the colossal and super colossal onion grades (Table 1). The analysis indicated differences among treatments for the small, medium, and jumbo categories, which in turn affected the results for marketable category. The results, however, did not clearly distinguish the effects of charcoal, irrigation, and the herbicide treatments. We suspect the weather conditions in 2011 may have contributed to these results. Because of the cooler conditions earlier in the season, the herbicides may not have been active to negatively affect the emerging onion seedlings. Importantly, the relatively heavy soil texture (silt loam) may have masked the effect of Dual Magnum and Outlook on emerging seedlings when applied prior to onion emergence.

The application of sprinkler irrigation to simulate rain after herbicide application before onion emergence, did not significantly impact stand or yield (Table 2). However, it should be noted that windy conditions at or around the time of planting delayed both the intended application dates of herbicide and sprinkler irrigation. Preemergent herbicides were not applied until 10 days after planting and the sprinkler application was applied another 10 days after the herbicides were applied, which may have impacted the spread and activity of herbicides on the emerging seedlings.

The dose response study will be repeated in 2012 to further evaluate onion response to simulated rain after preemergence application of herbicides. This study is important in order to determine the most efficacious rate. If favorable crop response is demonstrated, we will work with the manufacturers to pursue future registration of Dual Magnum and Outlook preemergence use on direct-seeded onions.

References

Felix, J., and J. Ishida. 2009. Use of activated charcoal to detoxify Dual Magnum® and Outlook® applied preemergence on direct-seeded onions. Oregon State University Malheur Agricultural Station Annual Report, Ext/CrS 131:115-118.

Felix, J., K. V. Osborne, and J. Ishida. 2010. Evaluation of Dual Magnum® and Outlook® used preemergence on direct-seeded dry bulb onions with activated charcoal. Oregon State University Malheur Agricultural Station Annual Report, Ext/CrS 132:120-125.

Table 1. Onion stand and yield in response to herbicides and activated charcoal rate at Malheur Experiment Station, Ontario, OR, 2011.

Herbicide[a]	Rate		Charcoal	Irrigation	Stand	Onion yield: Small	Medium	Jumbo	Colossal	Super colossal	Marketable yield
			lb/acre	0.5 in	plants/acre	cwt/acre					
Prowl H2O	2	pt/a	0	Yes	93,060	4.5	16.2	529.0	313.6	65.5	922.2
Prowl H2O	2	pt/a	0	No	102,465	4.8	55.2	479.1	274.0	86.4	853.6
Prowl H2O	2	pt/a	5	Yes	109,065	3.1	32.3	612.8	235.7	26.0	888.4
Prowl H2O	2	pt/a	5	No	81,675	6.7	16.5	419.1	231.3	59.4	723.8
Prowl H2O	2	pt/a	10	Yes	98,175	5.9	24.2	551.4	240.8	45.3	851.5
Prowl H2O	2	pt/a	10	No	92,070	2.9	20.5	514.2	280.8	59.4	868.4
Prowl H2O	2	pt/a	15	Yes	111,210	7.7	27.8	693.7	266.6	17.6	991.9
Prowl H2O	2	pt/a	15	No	104,445	4.9	15.5	611.8	341.8	79.8	1047.4
Prowl H2O	2	pt/a	20	Yes	110,550	4.2	29.1	615.1	273.4	38.4	940.9
Prowl H2O	2	pt/a	20	No	111,210	3.2	28.7	642.9	325.1	68.7	1,050.8
Prowl H2O	2	pt/a	25	Yes	107,580	6.6	27.2	588.7	263.8	29.9	896.5
Prowl H2O	2	pt/a	25	No	102,300	2.3	18.6	656.6	321.9	39.3	1,031.9
Dual Magnum	1.33	pt/a	0	Yes	86,625	3.9	19.4	443.6	267.6	82.5	807.7
Dual Magnum	1.33	pt/a	0	No	99,660	4.1	31.1	465.8	310.3	94.3	884.5
Dual Magnum	1.33	pt/a	5	Yes	100,485	5.0	15.7	529.8	281.0	52.4	877.2
Dual Magnum	1.33	pt/a	5	No	85,305	3.6	6.3	292.2	347.4	107.6	761.2
Dual Magnum	1.33	pt/a	10	Yes	107,910	6.5	29.7	667.0	201.5	17.0	899.6
Dual Magnum	1.33	pt/a	10	No	99,825	3.8	26.9	600.1	267.9	65.3	947.4
Dual Magnum	1.33	pt/a	15	Yes	95,040	5.8	19.1	541.9	270.2	26.0	852.1
Dual Magnum	1.33	pt/a	15	No	101,640	3.6	17.7	563.8	326.1	82.6	986.5
Dual Magnum	1.33	pt/a	20	Yes	110,220	3.7	25.3	652.9	250.5	39.6	956.9
Dual Magnum	1.33	pt/a	20	No	110,385	6.3	30.6	655.4	257.8	34.5	961.7
Dual Magnum	1.33	pt/a	25	Yes	98,670	8.9	32.3	580.6	291.3	34.2	920.2
Dual Magnum	1.33	pt/a	25	No	108,405	3.9	26.9	660.2	205.2	49.2	928.6
Outlook	21	fl. oz/a	0	Yes	94,545	2.4	31.7	420.7	337.3	86.2	858.3
Outlook	21	fl. oz/a	0	No	84,810	2.8	17.6	449.0	244.5	109.4	816.9
Outlook	21	fl. oz/a	5	Yes	95,370	6.5	22.4	524.0	292.0	65.8	895.8
Outlook	21	fl. oz/a	5	No	104,115	4.5	38.8	608.6	296.4	81.1	1,000.1
Outlook	21	fl. oz/a	10	Yes	70,785	7.1	20.1	353.5	197.4	45.9	610.8
Outlook	21	fl. oz/a	10	No	95,370	4.1	33.5	516.6	195.3	62.9	788.9
Outlook	21	fl. oz/a	15	Yes	93,225	6.1	24.9	489.8	273.7	30.8	808.3
Outlook	21	fl. oz/a	15	No	99,825	3.8	17.7	557.9	388.0	33.6	993.5
Outlook	21	fl. oz/a	20	Yes	108,240	3.5	22.5	667.7	246.9	28.6	957.2
Outlook	21	fl. oz/a	20	No	108,075	6.6	30.9	616.6	266.5	12.7	909.8
Outlook	21	fl. oz/a	25	Yes	97,845	3.9	31.9	553.8	286.7	35.8	890.2
Outlook	21	fl. oz/a	25	No	116,490	3.2	34.9	725.0	262.8	37.2	1,038.9
LSD (P = 0.05)					NS	5	21.3	232	NS	NS	275

[a] Prowl H2O was applied prior to onion emergence. All treatments were also sprayed with GoalTender at 0.5 pt/acre (0.25 lb ai/acre) and Buctril at 0.5 pt/acre (0.125 lb ai/acre) when onions were at the two-leaf stage.

Table 2. Onion stand and yield in response to application or no application of sprinkler irrigation to simulate rain. Malheur Experiment Station, Ontario, OR, 2011.

		Onion Yield					
Treatment	Plant stand	Small	Medium	Jumbo	Colossal	Super colossal	Marketable yield
	no./acre	cwt/acre					
No Irrigation	99,367	5.3	25.1	556.4	266.1	42.6	879.2
Irrigation	100,448	4.2	26.0	557.5	285.7	64.6	921.9
LSD *P* = 0.05	NS	NS	NS	NS	NS	NS	NS

EVALUATION OF DUAL MAGNUM® AND OUTLOOK® USED PREEMERGENCE ON DIRECT-SEEDED DRY BULB ONIONS WITH ACTIVATED CHARCOAL

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Introduction

Weeds are a major concern for onion growers in the Treasure Valley of eastern Oregon and southwestern Idaho. The sparse foliage and slow growth makes onions poor competitors with weeds. Large weeds can also reduce air circulation around plants, increasing the risk of foliar diseases. Yellow nutsedge particularly is a threat to direct-seeded onions throughout the Treasure Valley. Preliminary studies indicated the effectiveness of activated charcoal to neutralize Dual Magnum® (*S*-metolachlor) and Outlook® (dimethenamid-p) in the onion row when applied preemergence on direct-seeded onions (Felix and Ishida 2009, Felix et al. 2010). Currently, Dual Magnum and Outlook are registered for application to onion only when plants have attained the two-leaf stage. However, the best weed control results are realized when each herbicide is applied prior to weed emergence. The objective of this study was to evaluate the potential use of activated charcoal to neutralize Dual Magnum and Outlook immediately within the onion row when applied prior to onion emergence. Also, half of the treatments received 0.5 inch of overhead irrigation to evaluate the response of onion seedlings to herbicides applied prior to onion emergence with and without charcoal. **Dual Magnum and Outlook herbicides are not currently registered for pre-emergence application on direct-seeded dry bulb onions. Always read herbicide labels to ensure that the product is registered for the intended use.**

Materials and Methods

A field study was conducted in 2011 at the Malheur Experiment Station, Ontario, Oregon to evaluate the potential use of activated charcoal to neutralize Dual Magnum and Outlook within the onion row and protect the emerging plants from the herbicide effects. A similar study was conducted in 2010 and the results are presented in Table 2. The study also evaluated the effect of simulated rain (0.5 inches) shortly after herbicide application and before onion emergence.

The field was plowed and beds formed during fall 2010. Enough fertilizer to provide 44, 210, 210, 5, 8, and 5 lb/acre of nitrogen, phosphate, sulfur, zinc, and manganese was applied during fall 2010. The beds were harrowed during spring 2011 and onion variety ‘Vaquero’ was planted on April 13, 2011. The study followed a split-plot design with simulated rain (with and without) forming the main blocks into which herbicide rates were randomly assigned as subplots. The study had three replications and the plot size was 7.33 ft wide (4 22-inch beds) by 25 ft long. The entire trial was sprayed with Roundup® at 22 fl oz/acre (0.77 lb ae/acre) on April 22 to control volunteer wheat prior to onion emergence. Lorsban® 15G (chlorpyrifos at 0.125 lb ai/acre) was banded at 3.7 oz/1,000 ft of row over the entire field 5 days after planting as a preventive measure against onion maggots. Activated charcoal was applied in the onion row at the time of planting and herbicide treatments were applied on April 22, 2011.

The activated charcoal used was GRO-SAFE® (Norit Americas Inc., Atlanta, GA). Activated charcoal was applied using a modified planter fitted with a 25-gal Rear's NIFTY Tank Series (Rear's Manufacturing Co., Eugene, OR) and set to apply a 1-inch band of activated charcoal slurry directly over the onion row. Activated charcoal was applied at a rate of 25 lb/acre in 50 gal of water on the ground directly behind the onion planter's press wheel. After planting and charcoal application, Dual Magnum was applied preemergence at the rates of 1 pt/acre or 1.33 pt/acre (*S*-metolachlor at 0.95 lb ai/acre or 1.27 lb ai/acre) and Outlook at 10.5 fl oz/acre preemergence followed by 10.5 fl oz/acre when onions were at the two-leaf stage (dimethenamid-p at 0.49 lb ai/acre) or preemergence at 21 fl oz/acre (dimethenamid-p at 0.98 lb ai/acre). The study also included a grower standard, Prowl® H2O at 2 pt/acre (pendimethalin at 1 lb ai/acre) before onion emergence followed by Buctril® and Goal® 2XL herbicides that were applied when onions were at the two-leaf stage. The Dual Magnum and Outlook treatments were also treated with Goal 2XL and Buctril herbicides at 0.5pt/acre (oxyfluorfen and bromoxynil at 0.25 and 0.125 lb ai/acre, respectively) on June 9. An untreated control was also included.

Half of the main plots received sprinkler irrigation on April 27, 2011, simulating 0.5 inches of rainfall in 1 hour. The study area was furrow irrigated on May 7 and received regular irrigations to maintain adequate moisture in the top 12 inches of the soil profile.

Plant stand evaluations were accomplished by counting plants in the center two rows of the plot on May 20. The entire study area was sprayed with Poast at 1.5 pt/acre (sethoxydim at 0.28 lb ai/acre) tank-mixed with crop oil at 2 pts/acre on May 24. Plants were fertilized on June 22 using urea to supply 225 lb nitrogen/acre.

The insecticide Movento® was applied on June 13 at a rate of 5 fl oz/acre (spirotetramat at 0.078 lb ai/acre) plus Pierce methylated seed oil (MSO) at a rate of 1.5 pt/acre for onion thrips control. Onions were sprayed for thrips control again on June 22 and July 5 using a tank mixture of Radiant® at 10 fl oz/acre (spinetoram at 0.078 lb ai/acre) plus crop oil at 1 qt/100 gal of water. The final spray for thrips control was on June 24 with Lannate® at 3 pt/acre (methomyl at 0.9 lb ai/acre).

Plant tops were flailed on September 8 and the bulbs were lifted on September 13 and left on the ground to cure. Bulbs were handpicked from 15 ft of the 2 center rows of each plot on September 20. The onion bulbs were graded for yield and quality on September 23 following USDA standards. During grading, bulbs were separated according to quality: bulbs without blemishes (U.S. No. 1), split bulbs (No. 2), neck rot (bulbs infected with the fungus *Botrytis allii* in the neck or side), plate rot (bulbs infected with the fungus *Fusarium oxysporum*), and black mold (bulbs infected with the fungus *Aspergillus niger*). The U.S. No. 1 bulbs were graded according to diameter: small (<2¼ inches), medium (2¼-3 inches), jumbo (3-4 inches), colossal (4-4¼ inches), and super colossal (>4¼ inches). The data collected were subjected to analysis of variance and means compared using LSD at $P = 0.05$.

Results and Discussion

There was a three-way interaction (irrigation by herbicide by charcoal) for onion plant stand on May 22 for some treatments (Table 1). The best onion plant stand (104,445 plants/acre) was obtained from plots that were banded with charcoal, treated with Dual Magnum at 1.33 pt/acre, and irrigated prior to onion emergence. It is unclear why the plant stand was reduced when Dual Magnum at 1 pt/acre was applied in plots treated with and without charcoal but not irrigated. A similar response was observed when Outlook at 10.5 and 21 fl oz/acre were separately applied without charcoal and irrigation. The plant stand was not reduced in plots that received the grower standard treatment with and without charcoal and irrigation.

Evaluations of May 22 indicated significantly improved yellow nutsedge control when Dual Magnum and Outlook were applied prior to onion emergence. Yellow nutsedge was controlled 88 to 97 percent when Dual Magnum was applied at 1 pt/acre and 78 to 98 percent when it was applied at 1.33 pt/acre. Outlook at 10.5 fl oz/acre controlled yellow nutsedge 64 to 95 percent, whereas 21 fl oz/acre provided 89 to 99 percent control. Application of Outlook at 10.5 fl oz with charcoal but without irrigation provided the lowest yellow nutsedge control at 64 percent. The grower standard application of Prowl H20 at 2 pt/acre followed by GoalTender® and Buctril provided 55 to 79 percent yellow nutsedge control. Nutsedge control assessed on September 9 indicated reduced yellow nutsedge control across herbicide treatments (Table 1). However, yellow nutsedge control was relatively better for the plots that received charcoal and were irrigated at the beginning of the study.

The marketable onion yield was variable across treatments with a general trend of higher yields for treatments that were treated with charcoal (Table 1). The analysis indicated significant difference among treatments for the marketable onion yield (Table 3). The highest marketable onion yield was obtained when Dual Magnum and Outlook were applied at 1 pt/acre and 21 fl oz/acre, respectively. These results may have been influenced by the weather in 2011. The cool weather early in the season may have ameliorated the herbicide effects on treatments that did not receive charcoal.

It should be noted that windy conditions at or around the time of planting delayed the intended application date of herbicides and sprinkler irrigation. Preemergence herbicides were not applied until 9 days after planting and the sprinkler irrigation was applied 5 days after herbicide application. These factors coupled with the heavy silt loam soil may have masked the negative herbicide effects on treatments that did not receive charcoal. It is unclear how these treatments would perform under lighter sandy soil conditions. The study will be repeated in 2012.

References

Felix, J., and J. Ishida. 2009. Use of activated charcoal to detoxify Dual Magnum® and Outlook® applied pre-emergence on direct-seeded onions. Oregon State University Malheur Agricultural Station Annual Report, Ext/CrS131:115-118.

Felix, J., K. V. Osborne, and J. Ishida. 2010, Evaluation of Dual Magnum® and Outlook® used pre-emergence on direct-seeded dry bulb onions with activated charcoal. Oregon State University Malheur Agricultural Station Annual Report Ext/CrS132:120-125.

Table 1. Onion plant population (plants/acre) and yellow nutsedge control in response to preemergence application of Dual Magnum and Outlook herbicides with and without activated charcoal (25 lb/acre) and irrigation (0.5 inch) at the Malheur Experiment Station, Ontario, OR, 2011.

Treatment [a]	Rate		Charcoal	Irrigation	Plant stand	YNS Control [b]		Onion yield
					May 22	May 22	Sep 9	U.S. No. 1
			25 lb/acre	0.5 in	Plants/acre	%		cwt/acre
Prowl H2O	2	pt/a						
GoalTender	0.25	pt/a	Yes	No	74,085	55	3	228
Prowl H2O	2	pt/a	Yes	Yes	88,605	79	18	383
Prowl H2O	2	pt/a	No	No	85,140	70	0	257
Prowl H2O	2	pt/a	No	Yes	84,480	43	0	238
Dual Magnum	1	pt/a	Yes	No	70,950	88	67	371
Dual Magnum	1	pt/a	Yes	Yes	102,960	94	85	551
Dual Magnum	1	pt/a	No	No	69,795	93	82	554
Dual Magnum	1	pt/a	No	Yes	96,360	97	88	461
Dual Magnum	1.3	pt/a	Yes	No	88,440	78	38	353
Dual Magnum	1.3	pt/a	Yes	Yes	104,445	92	70	504
Dual Magnum	1.3	pt/a	No	No	81,510	88	65	421
Dual Magnum	1.3	pt/a	No	Yes	97,020	98	80	469
Outlook	10.5	fl. oz/a	Yes	No	72,435	64	18	297
Outlook	10.5	fl. oz/a	Yes	Yes	93,390	90	40	405
Outlook	10.5	fl. oz/a	No	No	74,250	85	20	339
Outlook	10.5	fl. oz/a	No	Yes	100,815	95	47	470
Outlook	21	fl. oz/a	Yes	No	93,720	89	52	458
Outlook	21	fl. oz/a	Yes	Yes	92,565	95	67	479
Outlook	21	fl. oz/a	No	No	68,805	93	57	480
Outlook	21	fl. oz/a	No	Yes	100,815	99	76	564
Untreated			Yes	No	77,385	0	0	190
Untreated			Yes	Yes	99,495	0	0	425
Untreated			No	No	80,355	0	0	313
Untreated			No	Yes	86,460	0	0	280
LSD ($P < 0.05$)					16,295	18	33	215

[a] Prowl H2O was applied prior to onion emergence. All treatments (except the untreated control) were also sprayed with GoalTender at 0.5 pt/acre (0.25 lb ai/acre) and Buctril at 0.5 pt/acre (0.125 lb ai/acre) when onions were at the two-leaf stage.

[b] Visual evaluation of the percentage of control of yellow nutsedge (YNS).

Table 2. Onion plant population (plants/acre) and yellow nutsedge control in response to preemergence application of Dual Magnum and Outlook herbicides with and without activated charcoal and irrigation at the Malheur Experiment Station, Ontario, OR, 2010.

Treatment [a]	Rate		Charcoal	Irrigation	Plant stand May 4	YNS Control [b] June 9, 2010	Onion yield U.S. No. 1
			25 lb/acre	0.5 in	Plants/acre	%	cwt/acre
Prowl H2O [c]	2	pt/a	No	No	103,148	74	464
Dual Magnum	1	pt/a	Yes	No	101,164	92	557
Dual Magnum	1	pt/a	Yes	Yes	82,915	87	410
Dual Magnum	1	pt/a	No	No	82,518	87	491
Dual Magnum	1	pt/a	No	Yes	64,666	90	292
Dual Magnum	1.3	pt/a	Yes	No	80,138	89	387
Dual Magnum	1.3	pt/a	Yes	Yes	92,436	92	379
Dual Magnum	1.3	pt/a	No	No	91,643	96	511
Dual Magnum	1.3	pt/a	No	Yes	68,236	92	260
Outlook	10.5	fl. oz/a	Yes	No	82,518	70	460
Outlook	10.5	fl. oz/a	Yes	Yes	84,898	81	380
Outlook	10.5	fl. oz/a	No	No	90,056	79	427
Outlook	10.5	fl. oz/a	No	Yes	55,144	83	242
Outlook	21	fl. oz/a	Yes	No	87,279	80	424
Outlook	21	fl. oz/a	Yes	Yes	71,410	88	256
Outlook	21	fl. oz/a	No	No	93,626	86	415
Outlook	21	fl. oz/a	No	Yes	38,085	82	142
Untreated			Yes	No	76,071	0	199
LSD (*P*<0.05)					28,158	21	158

[a] Prowl H2O was applied prior to onion emergence followed by GoalTender at 0.5 pt/acre (0.25 lb ai/acre) and Buctril at 0.5 pt/acre (0.125 lb ai/acre) when onions were at the two-leaf stage. Dual Magnum and Outlook treatments were also sprayed with GoalTender at 0.5 pt/acre (0.25 lb ai/acre) and Buctril at 0.5 pt/acre (0.125 lb ai/acre) when onions were at the two-leaf stage.

[b] Visual evaluation of the percentage of control of yellow nutsedge.

[c] Prowl H2O followed by GoalTender and Buctril plots in 2010 were in an area with very low yellow nutsedge density and were excluded from analysis.

Table 3. Onion yield in response to preemergence application of Dual Magnum and Outlook herbicides averaged over activated charcoal and irrigation treatments at the Malheur Experiment Station, Ontario, OR, 2011.

Treatment[a]	Rate		Onion yield					
			Small	Medium	Jumbo	Colossal	Super colossal	Marketable yield
			---------- cwt/acre ----------					
Prowl H2O	2	pt/a						
GoalTender	0.25	pt/a	35.2	102.1	171.2	3.2	0.0	276.6
Dual Magnum	1	pt/a	11.8	73.4	357.5	48.1	5.4	484.4
Dual Magnum	1.33	pt/a	17.5	99.5	314.9	19.3	3.1	436.8
Outlook	10.5	fl oz/a	19.1	102.8	247.4	22.6	5.1	377.8
Outlook	21	fl oz/a	12.3	88.0	354.5	47.8	5.1	495.4
Untreated			37.7	83.7	196.6	20.5	1.0	301.8
LSD $P < 0.05$			12.2	NS	84.7	32.4	NS	91.0

[a] Prowl followed by GoalTender was applied when onions were at the two-leaf stage. All treatment (except the untreated control) were also sprayed with GoalTender at 0.5 pt/acre (0.25 lb ai/acre) and Buctril at 0.5 pt/acre (0.125 lb ai/acre) when onions were at the two-leaf stage.

EVALUATION OF SUSTAIN® ADJUVANT FOR IMPROVED HERBICIDE WEED EFFICACY IN DIRECT-SEEDED ONION

Joel Felix and Joey Ishida, Oregon State University, Malheur Experiment Station, Ontario, OR, 2011

Introduction

Sustain® is a nonionic surfactant with a specific pinolene molecular weight polymer designed for soil applications. After application, the resin-based polymer binds the herbicides on the soil surface. The Sustain polymer is insoluble in water, hence the reason it helps to mitigate compounds from leaching or laterally moving. It does not completely inhibit lateral movement, but appears to keep more active ingredients of soil-applied herbicides in the target zone. In addition, Sustain is not rapidly degraded by microbes, and therefore could enhance the activity for soil-applied herbicides. Sustain also improves the contact, wetting, and adhesion of pesticides on plant leaves. The objective of this study was to evaluate weed control efficacy for herbicides applied with and without Sustain in direct-seeded bulb onion.

Materials and Methods

A field study was conducted in 2011 at the Malheur Experiment Station near Ontario, Oregon to evaluate weed control efficacy with various herbicides applied preemergence (PRE) or postemergence (POST) with and without Sustain on direct-seeded bulb onion. The wheat stubble was flailed and the field plowed during fall 2010. Enough fertilizer to provide 21, 102, 102, 2, and 1 lb/acre of nitrogen, phosphate, sulfur, manganese, and boron, respectively, was applied during fall 2010. The field was groundhogged and 22-inch-wide beds formed. On April 6, 2001, the beds were harrowed and reshaped. Onion variety 'Vaquero' was planted on April 7 in double rows spaced 3 inches apart and 4 inch spacing within the row. Each pair of rows was planted on beds spaced 22 inches apart.

Herbicide treatments were laid out in randomized complete block design with four replications. Individual plots measured 7.33 ft (4 beds wide) by 27 ft long. On April 14, Lorsban 15G® at 3.7 oz/1,000 ft of row (chlorpyrifos at 0.101 lb ai/acre) was banded and the soil surface was rolled. Roundup® was applied at 22 fl oz/acre (glyphosate at 0.77 lb ae/acre) on April 22 to control all emerged weeds prior to onion emergence. The first furrow irrigation was applied on May 8 and lasted 24 hours to supply about 4 inches of water (including overflow). All subsequent irrigations (12 times from June 10 to August 29, 2011) were of the same duration and delivered the same amount of water.

Herbicide treatments included Prowl H2O® (pendimethalin) at 0.98 lb ai/acre applied PRE on May 4 with and without Sustain at 1.04 lb ai/acre, GoalTender® (oxyfluorfen) at 0.25 lb ai/acre applied POST on May 25 with and without Sustain at 1.04 lb ai/acre, Prowl H2O at 0.98 lb ai/acre PRE followed by Outlook® (dimethenamid-p) at 0.98 lb ai/acre POST with and without Sustain at 1.04

lb ai/acre, and a grower standard that included Prowl H2O at 0.98 lb ai/acre PRE followed by GoalTender at 0.25 lb ai/acre POST. A nontreated control was also included. All herbicide treatments were applied using a CO_2-pressurized backpack sprayer with a boom equipped with 4 8002 EVS nozzles and calibrated to deliver 20 gal/acre at 35 PSI at 3 mph. Except for the nontreated control, all plots were sprayed with Poast (sethoxydim) at 0.287 lb ai/acre POST on May 24 to control grassy weeds.

Onion plants were sprayed with Movento® (spirotetramat) at 0.078 lb ai/acre tank-mixed with Pierce (crop oil concentrate) at 1.57 lb ai/acre on June 13 to control thrips. Plants were sidedressed with nitrogen at 225 lb/acre on June 21. Onion plants were sprayed again for thrips control on June 22 and July 5 using Radiant (spinetoram) at 0.078 lb ai/acre tank-mixed with a crop oil concentrate. Plots were visually evaluated for weed control and crop injury on June 27 and July 11 based on 0 to 100 percent; where 0 percent = no weed control or crop injury and 100 percent = complete weed control or complete crop kill.

Weeds were counted and harvested from 1 yd^2 in the center 2 rows of each plot on July 20 to quantify biomass accumulation. Weeds from each plot were placed in paper bags and transported to the greenhouse to air-dry and later weighed to determine the biomass. Onion tops were flailed on September 9 and onion bulbs were lifted on September 12 and left on the ground to cure until September 19 when bulbs were handpicked from the center two rows to determine yield. Bulbs were graded for quality and yield on September 23 based on USDA standards.

Results

There was no crop injury observed from any of the herbicide and Sustain treatments. Evaluations on June 27 (54 days after treatment) indicated improved weed control when Prowl H2O plus Sustain was applied prior to onion emergence compared to Prowl H2O alone (Table 1). The addition of Sustain into Prowl H2O improved control of common lambsquarters, redroot pigweed, and Pennsylvania smart weed by 30, 31, and 15 percent, respectively. Improved weed control with Prowl H2O plus Sustain was still apparent on July 11 (68 days after treatment). Control of common lambsquarters, redroot pigweed, and Pennsylvania smartweed improved 13, 18, and 16 percent, respectively for Prowl H2O plus Sustain compared to Prowl H2O alone (Table 2). Total weed biomass on July 20 (77 days after treatment) was 10 oz/yd^2 for plots treated with Prowl H2O plus Sustain compared to 17 oz/yd^2 for Prowl H2O alone (Table 2).

The grower standard (Prowl H2O followed by GoalTender) provided the greatest onion yield (1,003.9 cwt/acre) compared to the other herbicide treatments (Table 3). This was expected because plots treated with Prowl H2O with and without Sustain did not receive post-emergence applications like the grower standard. The GoalTender with and without Sustain treatments did not receive the preemergence application of Prowl H2O. Similarly, Prowl H2O with and without Sustain followed by Outlook or Dual Magnum treatments were not treated with postemergence GoalTender, which is more effective on weeds that have already emerged.

The results indicated that the application of Prowl H2O plus Sustain prior to onion emergence improved weed control compared to Prowl H2O alone. The study will be repeated in 2012 to confirm these results.

Table 1. Weed control on June 27, 2011 (54 days after treatment) with various herbicides applied with and without Sustain at the Malheur Experiment Station, Ontario, OR.

Treatment	Rate	Application timing[b]	Crop injury	Weed control[a] Common lambsquarters	Hairy nightshade	Redroot pigweed	Pennsylvania smartweed	Kochia
	lb ai/acre		--- % ---	--- % ---				
Untreated			0	0	0	0	0	0
Prowl H2O Sustain	0.98 1.04	A A	0	96 a	78 c	85 a	96 a	94 a
Prowl H2O	0.98	A	0	66 b	83 bc	54 b	81 b	80 a
GoalTender Sustain	0.25 1.04	B B	0	74 b	100 a	100 a	95 a	98 a
GoalTender	0.25	B	0	73 b	99 a	99 a	86 ab	89 a
Prowl H2O Sustain Outlook Sustain	0.98 1.04 0.98 1.04	A A B B	0	74 b	84 bc	98 a	91 ab	98 a
Prowl H2O Outlook	0.98 0.98	A B	0	73 b	97 ab	95 a	90 ab	94 a
Prowl H2O Sustain Dual Magnum Sustain	0.98 1.04 1.27 1.04	A A B B	0	98 a	90 abc	91 a	85 ab	98 a
Prowl H2O GoalTender (grower standard)	0.98 0.25	A B	0	99 a	99 a	100 a	93 ab	98 a

[a] Means within a column followed by the same letter are not significantly different according to LSD $P = 0.05$.
[b] Application timing: A = pre-emergence, B = post-emergence.

Table 2. Weed control on July 11, 2011(68 days after treatment) and dry weight on July 20, 2011 for different herbicides applied with and without Sustain at the Malheur Experiment Station, Ontario, OR.

Treatment	Rate	Application timing[b]	Weed control[a] Common lambsquarters	Hairy nightshade	Redroot pigweed	Pennsylvania smartweed	Kochia	Weed dry weight
	lb ai/acre		%					oz/yd^2
Untreated			0	0	0	0	0	34
Prowl H2O Sustain	0.98 1.04	A A	93 a	63 c	81 b	99 a	96 ab	10 b
Prowl H2O	0.98	A	80 b	79 bc	63 c	83 bc	93 abc	17 a
GoalTender Sustain	0.25 1.04	B B	95 a	100 a	100 a	91 abc	90 bc	2 cd
GoalTender	0.25	B	96 a	95 ab	99 a	80 c	85 c	8 bc
Prowl H2O Sustain Outlook Sustain	0.98 1.04 0.98 1.04	A A B B	98 a	83 abc	97 ab	95 ab	100 ab	2 cd
Prowl H2O Outlook	0.98 0.98	A B	89 ab	95 ab	96 ab	89 abc	93 abc	2 cd
Prowl H2O Sustain Dual Magnum Sustain	0.98 1.04 1.27 1.04	A A B B	98 a	80 abc	95 ab	90 abc	99 ab	5 bcd
Prowl H2O GoalTender (Grower standard)	0.98 0.25	A B	98 a	100 a	100 a	91 abc	100 a	<1 d

[a] Means within a column followed by the same letter are not significantly different according to LSD *P* = 0.05.
[b] Application timing: A = pre-emergence, B = post-emergence.

Table 3. Onion yield in response to different herbicides applied with and without Sustain at the Malheur Experiment Station, Ontario, OR, 2011.

Treatment	Rate	Application timing[b]	Onion yield[a]					
			Small	Medium	Jumbo	Colossal	Super colossal	U.S # 1
	lb ai/acre		cwt/acre					
Untreated			2.4	0	0	0	0	0
Prowl H2O	0.98	A	11.8 ab	148.8 a	591.9 bc	53.2 b	0 b	793.8 b
Sustain	1.04	A						
Prowl H2O	0.98	A	11.7 ab	89.0 ab	572.8 c	52.8 b	6.3 ab	720.9 b
GoalTender	0.25	B	9.9 ab	49.5 b	714.6 ab	80.0 b	9.7 ab	853.7 b
Sustain	1.04	B						
GoalTender	0.25	B	9.8 ab	72.8 ab	700.2 abc	44.8 b	0 b	817.7 b
Prowl H2O	0.98	A	4.9 ab	74.7 ab	631.7 bc	67.2 b	6.8 ab	780.4 b
Sustain	1.04	A						
Outlook	0.98	B						
Sustain	1.04	B						
Prowl H2O	0.98	A	8.2 ab	59.5 ab	686.9 abc	81.4 b	6.6 ab	834.4 b
Outlook	0.98	B						
Prowl H2O	0.98	A	12.4 a	91.1 ab	608.8 bc	49.0 b	0 b	748.9 b
Sustain	1.04	A						
Dual Magnum	1.27	B						
Sustain	1.04	B						
Prowl H2O	0.98	A	3.9 b	21.7 b	787.2 a	176.9 a	12.6 a	1,003.9 a
GoalTender	0.25	B						
(Grower standard)								

[a] Means within a column followed by the same letter are not significantly different according to LSD *P* = 0.05.
[b] Application timing: A = pre-emergence, B = post-emergence.

EVALUATION OF PYROXASULFONE FOR WEED CONTROL IN DIRECT-SEEDED ONION

Joel Felix and Joey Ishida, Malheur Experiment Station, Oregon State University, Ontario, OR, 2011

Introduction

Relatively fewer herbicides are registered for weed control in direct-seeded onions and vegetables in general compared to agronomic crops such as corn. Consequently, evaluation of herbicides for weed control in specialty crops is necessary because most product labels include only major crops (wheat, corn, soybean, and cotton) when they are first registered. Therefore, evaluation of herbicide performance is the first step before products can be registered by the U.S. Environmental Protection Agency for use on any specialty crop. Weed control in direct-seeded onion is essential in order to realize acceptable bulb size and yield. To that end, the weed program at the Malheur Experiment Station endeavors to evaluate new herbicides that come on the market and to determine their fitness for weed control in direct-seeded onions grown under furrow irrigation. The objective of this study was to evaluate KIH-485 (pyroxasulfone) for weed efficacy and tolerance by direct-seeded dry bulb onion grown under furrow-irrigation conditions.

Materials and Methods

Onion response to KIH-485 and its weed control efficacy under furrow-irrigated conditions were evaluated in 2011 at the Malheur Experiment Station, Ontario, Oregon. The herbicide KIH-485 was applied at 1.06, 1.28, or 1.7 oz ai/acre at one of the following four timings: preplant incorporated (PPI), preemergence (PRE), or when onion plants were at the one-leaf or two-leaf stage.

The wheat stubble was flailed and the field plowed during fall of 2010. Fertilizer was immediately applied to provide 21, 102, 102, 2, and 1 lb/acre of nitrogen, phosphate, sulfur, manganese, and boron, respectively. The field was later groundhogged and 22-inch-wide beds formed. The beds were harrowed and reshaped on April 6, 2011. The PPI herbicide treatments were applied on April 7 and onion variety ‘Vaquero’ planted later that day. Onion seeds were planted in double rows spaced 3 inches apart and 4-inch spacing within each row. Double rows were planted on beds spaced 22 inches apart. The treatments were laid out in randomized complete block design with four replications. Individual plots measured 7.33 ft (4 beds wide) by 27 ft long. On April 14, Lorsban® 15G at 3.7 oz/1,000 ft of row (chlorpyrifos at 0.101 lb ai/acre) was banded over the top of the onion rows and the soil surface was rolled. Roundup® was applied at 22 fl oz/acre (glyphosate at 0.77 lb acid equivalent [ae]/acre) on April 22 to control all weeds that had emerged prior to onion emergence.

The first furrow irrigation was applied on May 8 and lasted 24 hours to supply about 4 inches of water (including runoff). All subsequent irrigations (12 times from June 10 to August 29, 2011) were of the same duration and delivered the same amount of water.

The postemergence treatments were applied May 11 and May 22 when onions were at the one- and two-leaf stages, respectively. GoalTender® and Buctril® were applied at the rates of 0.5 pt/acre equivalent to oxyfluorfen at 0.25 lb ai/acre and bromoxynil at 0.125 lb ai/acre, respectively.

Onion plants were sprayed with Movento® (spirotetramat) at 0.078 lb ai/acre tank-mixed with Pierce (crop oil concentrate) at 1.57 lb ai/acre on June 13 to control thrips. Plants were sidedressed with urea fertilizer on June 21 to supply nitrogen at 225 lb/acre. Onion plants were sprayed again for thrips control on June 22 and July 5 using Radiant® (spinetoram) at 0.078 lb ai/acre tank-mixed with a crop oil concentrate. Plots were visually evaluated for weed control and crop injury on May 10 and July 15 based on 0 to 100 percent where 0 percent = no weed control or crop injury and 100 percent = complete weed control or complete crop kill.

Results and Discussion

There was no onion injury observed from any of the herbicide rates and application timings evaluated in this study (Tables 1 and 2). Early season control for common lambsquarters varied by the herbicide application timing and ranged from 75 to 90 percent compared to 98 percent for Prowl H2O® (Table 1). Control for hairy nightshade ranged from 80 to 90 percent, while redroot pigweed was controlled 80 to 90 percent. Kochia control ranged from 85 to 97 percent across herbicide rates and application timing.

Postemergence application of GoalTender at 2 oz ai/acre improved the midseason weed control regardless of the KIH-485 rate and application timing (Table 2). Common lambsquarters was controlled 85 to 90 percent compared to 98 percent for Prowl H2O followed by GoalTender (grower standard). Midseason control for hairy nightshade was 90 to 98 percent compared to 100 percent for the grower standard. Delaying the application of KIH-485 until onions were at the two-leaf stage provided lower hairy nightshade control (90 percent). Application of KIH-485 at 1.06 to 1.7 oz ai/acre followed by GoalTender at 2 oz ai/acre provided almost complete control for redroot pigweed (97 to 100 percent) regardless of the application timing. Kochia control ranged from 90 to 99 percent with the lower control associated with KIH-485 at 1.06 to 1.7 oz ai/acre applied when onions were at one- and two-leaf stages.

The number of onion bulbs varied across herbicide treatments (Table 3); small bulbs ranged from 1,782 to 5,346 bulbs/acre, medium bulbs ranged from 10,494 to 21,780 bulbs/acre, while jumbo bulbs varied from 72,666 to 100,386/acre. There was no difference in the number of jumbo bulbs across herbicide treatment rates and application timing. The highest number of colossal bulbs (12,276/acre) was obtained when KIH-485 was applied at 1.7 oz ai/acre prior to planting onion. Similarly, the highest number of U.S. No. 1 onion bulbs was obtained when KIH-485 was applied prior to onion emergence at 1.28 and 1.7 oz ai/acre. Application of KIH-485 at 1.28 oz ai/acre when onions were at the one-leaf stage produced the lowest number of bulbs (89,496/acre).

Yield for the medium, colossal, and super colossal categories varied across herbicide treatments

(Table 4); however, when grouped together, there was no significant difference among KIH-485 herbicide rates and application timing for the U.S. No. 1 category or the total yield per acre.

These results indicated that KIH-485 may be a potential herbicide for weed control in direct-seeded dry bulb onions. It is unclear whether or not the mild weather in 2011 played any role in these results, so we do not know whether KIH-485 would damage onions with hotter weather. Therefore, this study will be repeated in 2012 to confirm these results and evaluate further the weed control and onion response to this product.

Table 1. Weed control on May 10 in direct-seeded dry bulb onion treated with KIH-485 (pyroxasulfone) at the Malheur Experiment Station at Ontario, OR, 2011.

Treatment	Rate	Timing[a]	Crop injury	Weed control: Common lambsquarters	Weed control: Hairy nightshade	Weed control: Redroot pigweed	Weed control: Kochia
	oz ai/acre		no./acre				
Untreated			0	0	0	0	0
KIH-485	1.06	A	0	80	80	85	90
KIH-485	1.28	A	0	85	85	90	90
KIH-485	1.7	A	0	85	90	90	97
KIH-485	1.06	B	0	85	85	90	90
KIH-485	1.28	B	0	85	85	95	90
KIH-485	1.7	B	0	90	90	95	95
KIH-485	1.06	C	0	75	80	80	85
KIH-485	1.28	C	0	80	80	85	85
KIH-485	1.7	C	0	80	80	85	85
KIH-485	1.06	D	0	--[b]	--	--	--
KIH-485	1.28	D	0	--	--	--	--
KIH-485	1.7	D	0	--	--	--	--
Prowl H2O (Grower standard)	11.4	B	0	98	98	98	98
LSD (*P* = 0.05)			--	5	8	9	7

[a] Herbicide application timing: A = preplant incorporated; B = preemergence; C = onion at one-leaf stage; D = onion at 2-leaf stage.
[b]Ratings taken before the treatments were applied.

Table 2. Weed control on July 15 in direct-seeded onion treated with KIH-485 (pyroxasulfone) at the Malheur Experiment Station at Ontario, OR, 2011.

Treatment	Rate	Timing[a]	Crop injury	Weed control: Common lambsquarters	Hairy nightshade	Redroot pigweed	Kochia
	oz ai/acre		------------------------------ no./acre ------------------------------				
Untreated			0	0	0	0	0
KIH-485 GoalTender	1.06 2	A D	0	90	95	97	99
KIH-485 GoalTender	1.28 2	A D	0	95	98	98	99
KIH-485 GoalTender	1.7 2	A D	0	90	98	98	99
KIH-485 GoalTender	1.06 2	B D	0	95	98	99	99
KIH-485 GoalTender	1.28 2	B D	0	95	98	99	99
KIH-485 GoalTender	1.7 2	B D	0	95	98	99	99
KIH-485 GoalTender	1.06 2	C D	0	90	98	98	99
KIH-485 GoalTender	1.28 2	C D	0	90	98	98	90
KIH-485 GoalTender	1.7 2	C D	0	90	98	98	90
KIH-485 GoalTender	1.06 2	D D	0	80	90	95	90
KIH-485 GoalTender	1.28 2	D D	0	90	90	95	90
KIH-485 GoalTender	1.7 2	D D	0	85	90	95	90
Prowl H2O GoalTender (Grower standard)	11.4 2	B D	0	98	100	100	100
LSD (*P* = 0.05)			--	5	7	NS	8

[a] Herbicide application timing: A = preplant incorporated; B = preemergence; C = onion at one-leaf stage; D = onion at 2-leaf stage.

Table 3. Plant stand in response to KIH-485 (pyroxasulfone) application on direct-seeded onion at the Malheur Experiment Station at Ontario, OR, 2011.

Treatment	Rate	Timing[a]	Number of onion bulbs						
			Small	Medium	Jumbo	Colossal	Super colossal	U.S. No. 1	Total number
	oz ai/acre		no./acre						
Untreated			2,970	16,830	72,468	2,772	0	92,070	95,040
KIH-485	1.06	A	4,158	18,018	90,486	5,346	198	114,048	118,206
GoalTender	2	D							
KIH-485	1.28	A	2,574	11,682	90,882	9,702	1,386	113,652	116,226
GoalTender	2	D							
KIH-485	1.7	A	2,574	10,692	72,666	12,276	594	96,228	98,802
GoalTender	2	D							
KIH-485	1.06	B	3,168	18,018	97,218	3,564	0	118,800	121,968
GoalTender	2	D							
KIH-485	1.28	B	2,178	17,424	98,604	4,950	0	120,978	123,156
GoalTender	2	D							
KIH-485	1.7	B	5,346	21,780	100,386	3,168	0	125,334	130,680
GoalTender	2	D							
KIH-485	1.06	C	3,762	18,810	92,070	7,524	396	118,800	122,562
GoalTender	2	D							
KIH-485	1.28	C	3,366	10,494	74,646	4,158	198	89,496	92,862
GoalTender	2	D							
KIH-485	1.7	C	2,178	15,840	85,536	4,356	594	106,326	108,504
GoalTender	2	D							
KIH-485	1.06	D	2,574	13,068	96,624	7,920	0	117,612	120,186
GoalTender	2								
KIH-485	1.28	D	1,782	14,256	97,218	5,346	396	117,216	118,998
GoalTender	2								
KIH-485	1.7	D	2,970	11,880	81,774	5,544	0	99,198	102,168
GoalTender	2								
Prowl H2O	11.4	B	3,168	17,424	90,684	6,336	0	114,444	117,612
GoalTender (Grower std)	2	D							
LSD (P = 0.05)			3,206	10,860	NS	6,608	691	34,084	34,979

[a] Herbicide application timing: A = preplant incorporated; B = preemergence; C = onion at one-leaf stage; D = onion at two- leaf stage.

Table 4. Onion yield in response to KIH-485 (pyroxasulfone) application on direct-seeded onion at the Malheur Experiment Station at Ontario, OR, 2011.

Treatment	Rate	Timing[a]	Onion yield						
			Small	Medium	Jumbo	Colossal	Super colossal	U.S. No. 1	Total yield
	oz ai/acre		cwt/acre						
Untreated			6.3	64.6	567.5	31.1	0.0	663.1	669.4
KIH-485 GoalTender	1.06 2	A D	8.9	66.4	681.0	60.2	3.4	811.0	819.9
KIH-485 GoalTender	1.28 2	A D	5.7	42.2	688.2	111.3	18.9	860.6	866.3
KIH-485 GoalTender	1.7 2	A D	6.3	42.2	647.3	147.9	9.8	847.2	853.5
KIH-485 GoalTender	1.06 2	B D	8.0	67.8	738.1	39.5	0.0	845.4	853.4
KIH-485 GoalTender	1.28 2	B D	4.7	67.5	759.4	58.1	0.0	885.0	889.7
KIH-485 GoalTender	1.7 2	B D	12.8	89.0	654.9	39.0	0.0	783.0	795.8
KIH-485 GoalTender	1.06 2	C D	7.9	70.1	682.7	89.0	6.9	848.7	856.6
KIH-485 GoalTender	1.28 2	C D	8.0	38.1	588.9	49.2	2.9	679.1	687.0
KIH-485 GoalTender	1.7 2	C D	6.3	61.4	650.3	50.9	9.8	772.5	778.8
KIH-485 GoalTender	1.06	D	5.4	51.8	730.9	96.8	0.0	879.4	884.9
KIH-485 GoalTender	1.28	D	4.2	52.8	753.4	64.7	6.9	877.9	882.0
KIH-485 GoalTender	1.7	D	7.0	41.1	657.6	66.0	0.0	764.7	771.7
Prowl H2O GoalTender (Grower standard)	11.4 2	B D	7.0	68.7	686.1	75.5	0.0	830.3	837.3
LSD (P = 0.05)			7	43.1	NS	78.3	10.9	NS	NS

[a] Herbicide application timing: A = preplant incorporated; B = preemergence; C = onion at one- leaf stage; D = onion at two-leaf stage.

EVALUATION OF FOMESAFEN (REFLEX®) HERBICIDE FOR WEED CONTROL IN RANGER RUSSET POTATO AND RESPONSE OF SUBSEQUENT CROPS TO SOIL RESIDUES

Joel Felix and Joey Ishida, Malheur Experiment Station, Oregon State University, Ontario, OR, 2011

Introduction

Weed control is an important component of potato production. Weeds present a major production concern for potato growers because they often reduce potato yield, quality, and may possibly serve as alternative hosts for other crop pests. In eastern Oregon, furrow irrigation and warm growing conditions provide ideal conditions for weed growth. Also, yellow nutsedge is a major weed problem in eastern Oregon agriculture. It is imperative that weed control programs in every crop grown in a rotation include products that provide control of yellow nutsedge. Fomesafen (Reflex®) is currently going through the registration process with the U.S. Environmental Protection Agency (EPA) (Glenn Letendre, Syngenta Crop Protection, personal communication) for use in different crops for weed control. The herbicide has potential to control yellow nutsedge in potato, especially when used as a tank-mix partner with other products including *S*-metolachlor (Dual Magnum®) and dimethenamid-p (Outlook®). Studies conducted at the Malheur Experiment Station in 2010 and 2011 indicated that fomesafen controls most annual broadleaf weeds and provides partial control of yellow nutsedge.

The registration of fomesafen will bring new herbicide chemistry for weed control in potato. Use of different herbicide groups to control weeds is recommended as a tactic to avoid selection for weed resistance to herbicides. At the same time, understanding the response of crops grown following potato to fomesafen soil residues is needed to generate support data that are required for soliciting EPA for a Section 24-C registration to use fomesafen on potato in Oregon. Growers are likely to experience better weed control by tank-mixing fomesafen with either *S*-metolachlor or dimethenamid-p, which are generally used as foundation products for weed control programs in potato. Growers whose fields are infested with yellow nutsedge prefer to use dimethenamid-p and *S*-metolachlor herbicides because they provide effective control of the weed. Better weed control produces high quality potato, which in turn benefits growers, the processing industry, and consumers of this nutritious produce.

This study is part of broader efforts to evaluate herbicides for use on potato in managing yellow nutsedge in the Treasure Valley of eastern Oregon. Because the herbicide half-life in the soil is affected by soil pH, it is crucial to evaluate fomesafen performance in the high pH soils of eastern Oregon. We need to determine the response of crops grown following potato to fomesafen soil residues. Our goal is to provide growers with tools to manage weeds without affecting subsequent crops grown in rotation with potato.

The overall goal of these studies was to evaluate new effective herbicide combinations for weed control in potato. The specific objectives were (1) evaluate fomesafen herbicide for weed control when applied alone or as a tank-mix partner with standard potato herbicides; and (2) evaluate the response of crops grown following potato (rotational crops) to fomesafen soil residues. Objective 2 will be completed during the 2012 season.

Materials and Methods

Two studies were established in 2011 at the Malheur Experiment Station in a field previous planted to wheat. Tillage operations were done the preceding fall following standard practices for potato production. The soil was an Owyhee silt loam with a pH 7.7 and 1.89 percent organic matter. The first study aimed to evaluate herbicides for weed control in potato, while the second study was to prepare the field to study the response of rotational crops (in 2012) to the fomesafen soil residues applied to potato in 2011. Seven rotational crops (winter and spring wheat, onion, sugar beet, sweet corn, and barley) will be planted in 2012 to assess the response to fomesafen soil residues.

The herbicide evaluation study (objective 1) followed a randomized complete block design with four replications. Individual plots were 9 ft wide (3 rows) by 30 ft long. The study had seven treatments (Tables 1–3). Plots were monitored for potato plant injury and evaluated for weed control at 19 and 54 days after treatment (DAT). Evaluations were based on a scale of 0-100 percent (0 = no weed control/no crop injury and 100 = complete weed control/total crop damage).

The study of the effect of fomesafen soil residues on rotational crops (objective 2) followed a split-plot design with four herbicide treatments forming the main plots onto which seven rotational crops will be randomly assigned as subplots in 2012. Each main plot was 63 ft wide (21 rows) by 30 ft long with 3 replications. Treatments for the fomesafen soil residues effects experiments are presented in Table 4. In order to minimize weed competition in crops grown in 2012, plots for the fomesafen soil residue study were kept weed free with periodic hand weeding when vine growth could still allow walking through the rows.

Both studies were planted with ‘Ranger Russet’ potato seed pieces on April 20, 2011 using a 2-row assist-feed planter with 9-inch spacing within the row in 36-inch center beds. Emergence was observed on May 26, 2011. Plots were fertilized based on soil tests and all other recommended production practices including spraying for insects and diseases were followed.

Herbicide treatments for both studies were applied on May 21, 2011 before potato and weed emergence using a CO_2-pressurized backpack sprayer fitted with a boom equipped with six EVS8002 flat-fan nozzles calibrated to deliver 20 gal of spray solution per acre. Plots were irrigated immediately after herbicide application to incorporate herbicides into the soil. Subsequent irrigations were scheduled based on six Watermark soil moisture sensors (Irrometer Co., Riverside, CA) connected to an AM400 data logger (M.K. Hansen Co., Wenatchee, WA) to prevent the soil at the seed-piece depth from drying beyond 60 kPa soil water tension.

A mechanical harvester was used to lift the potatoes at maturity on October 31, 2011 from one row per plot to determine yield. All other potatoes were hand-picked and disposed of to avoid volunteer plants in subsequent crops. Potatoes were transported to the station and graded following USDA recommended standards. The data were subjected to analysis of variance using PROCGLM in Statistical Analysis Software (SAS) and means were compared using Fisher's protected least significant difference procedure at $P \leq 0.05$.

Results and Discussion

Evaluations on June 9 indicated that there was no significant potato injury from the herbicide treatments, except for transient foliar yellowing (Table 1). Herbicide treatments provided complete control for common lambsquarters, redroot pigweed, and barnyardgrass. Control of volunteer wheat on June 9 ranged from 90 to 100 percent among the different herbicide treatments. Midseason weed control on July 14 was 100 percent for common lambsquarters and barnyardgrass (Table 2). Control for redroot pigweed ranged from 98 to 100 percent among the herbicide treatments. Volunteer wheat control ranged from 90 to 100 percent. There were no differences in potato yield among herbicide treatments for the 4- to 6-oz and the over 12 oz potato categories (Table 3). The yield varied among herbicide treatments for the 6 to 12 oz category, whose yield ranged from 272 to 318 cwt/acre. The U.S. No. 1 potato yield varied among herbicide treatments because it was generally influenced by the 6- to 12-oz potato category. Potato yield for the U.S. No. 2 and under 4 oz categories was similar among herbicide treatments. The results suggest that herbicide treatments that included fomesafen provided complete weed control and potato yield was similar to a grower standard of *S*-metolachlor plus pendimethalin plus Eptam® at 1.49, 0.95, and 4.38 lb ai/acre, respectively.

Plots for the evaluation of rotational crop response to fomesafen soil residues were kept weed-free throughout the season. Even though the potato yield for the 4- to 6-oz and 6- to 12-oz categories varied among treatments, the total U.S. No.1 yield was similar among herbicide treatments (Table 4). The marketable and U.S. No.2 categories were also similar across treatments. Treatments varied in the potato yield for the under4-oz category that ranged from 64 to 85 cwt/acre. These results corroborate our previous results in 2010 that fomesafen is a valuable tank-mix herbicide partner for weed control in potato. The response of crops grown following potato will be assessed in 2012.

Table 1. Weed control in potato on June 9, 2011 with different herbicides at the Malheur Experiment Station, Ontario, OR, 2011.

Treatment	Rate	Crop injury	Weed control: Common lambsquarters	Redroot pigweed	Barnyardgrass	Volunteer wheat
	lb ai/acre	%				
Untreated		0	0	0	0	25
Linuron + Dimethenamid-p	0.75 0.66	0	100	100	100	100
Linuron + *S*-metolachlor	0.75 1.43	0	100	100	100	90
S-metolachlor + Pendimethalin + Fomesafen	1.27 0.95 0.25	3	100	100	100	95
S-metolachlor + Pendimethalin + Fomesafen	1.27 0.95 0.5	3	100	100	100	95
Fomesafen + *S*-metolachlor + Metribuzin	0.25 1.63 0.312	0	100	100	100	100
S-metolachlor + Pendimethalin + Eptam	1.43 0.95 4.38	0	100	100	100	100
LSD (P = 0.05)		2.5	--	--	--	29.2
Standard deviation		1.7	0.0	0.0	0.0	19.7

Table 2. Weed control in potato on July 14, 2011 with different herbicides at the Malheur Experiment Station, Ontario, OR, 2011.

Treatment	Rate	Crop injury	Weed control: Common lambsquarters	Redroot pigweed	Barnyardgrass	Volunteer wheat
	lb ai/acre	%				
Untreated		0a	0	0	0	25
Linuron + Dimethenamid-p	0.75 0.66	0a	100	98	100	100
Linuron + *S*-metolachlor	0.75 1.43	0a	100	100	100	90
S-metolachlor + Pendimethalin + Fomesafen	1.27 0.95 0.25	0a	100	100	100	95
S-metolachlor + Pendimethalin + Fomesafen	1.27 0.95 0.5	0a	100	100	100	95
Fomesafen + *S*-metolachlor + Metribuzin	0.25 1.63 0.312	0a	100	99	100	100
S-metolachlor + Pendimethalin + Eptam	1.43 0.95 4.38	0a	100	100	100	100
LSD ($P = 0.05$)		NS	--	2.0	--	29.2
Standard deviation		0.0	0.0	1.4	0.0	19.7

Table 3. Russet Ranger potato yield in response to different herbicides applied preemergence at the Malheur Experiment Station, Ontario, OR, 2011.

		Potato yield							
		U.S. No.1							
Treatment	Rate	4-6 oz	6-12 oz	>12 oz	Total	US No. 2	Marketable	<4 oz	Total
	lb ai/acre	cwt/acre							
Untreated		117.3	222.8	33.0	373.1	2.4	375.5	75.2	450.6
Linuron + Dimethenamid-p	0.75 0.66	114.7	272.1	69.4	456.1	8.0	464.1	65.8	529.9
Linuron + *S*-metolachlor	0.75 1.43	102.7	318.6	43.9	465.2	2.7	467.9	66.8	534.8
S-metolachlor + Pendimethalin + Fomesafen	1.27 0.95 0.25	134.9	259.3	53.7	447.9	8.0	456.0	64.1	520.1
S-metolachlor + Pendimethalin + Fomesafen	1.27 0.95 0.5	119.0	304.4	68.5	491.8	4.5	496.4	70.8	567.2
Fomesafen + *S*-metolachlor + Metribuzin	0.25 1.63 0.312	112.2	282.2	53.7	448.1	2.3	450.4	62.5	512.9
S-metolachlor + Pendimethalin + Eptam	1.43 0.95 4.38	116.0	275.9	42.9	434.7	2.8	437.5	80.4	517.9
LSD (*P* = 0.05)		NS	66.0	NS	78.4	NS	76.5	NS	79.6
Standard deviation		28.65	44.4	27.74	52.8	4.09	51.5	15.34	53.6

Table 4. Potato yield in response to fomesafen (Reflex®) herbicide treatments at the Malheur Experiment Station, Ontario, OR. 2011.

Treatment	Rate	U.S. No. 1				Marketable	U.S. No. 2	<4 oz	Total yield
		4-6 oz	6-12 oz	>12 oz	Total				
	lb ai/acre	-----	-----	-----	----- cwt/acre -----	-----	-----	-----	-----
Fomesafen	0.25	102	306	77	485	490	5	64	554
Fomesafen	0.5	117	259	56	431	436	5	69	506
S-metolachlor + Fomesafen	1.27 0.25	117	283	66	466	473	7	71	545
S-metolachlor + Pendimethalin	1.27 0.95	129	294	45	468	475	7	85	561
LSD (*P* = 0.05)		25	35	NS	NS	NS	NS	12.7	64.9
Standard deviation		12.4	17.7	30.3	36.3	31.2	4.5	6.4	32.5

INVESTIGATE SWEET POTATO CULTIVARS AND IRRIGATION CRITERIA FOR THE TREASURE VALLEY

Joel Felix, Clinton Shock, Joey Ishida, and Erik Feibert, Malheur Experiment Station, Oregon State University, Ontario, OR, 2011

Introduction

Sweet potato is a versatile crop cultivated mainly for tuber production. It is a long-season crop grown mainly in the southeastern United States and in California. Research suggests that the availability of irrigation water together with high temperatures during summer favors production of high-quality sweet potatoes in eastern Oregon. Recently, growers have indicated interest in growing sweet potato as a new crop in eastern Oregon. The valley has a number of crop produce processors who are willing to buy sweet potatoes grown locally as a strategy to cut the costs associated with sweet potato trucking from California and the southeastern United States. Purchasing locally produced sweet potatoes could significantly reduce the carbon footprint of sweet potato processors in the Treasure Valley. Also, growers would be able to develop niche marketing for a crop that is loved by most consumers. Newly developed sweet potato varieties will produce mature tubers in 80 to 90 days, suggesting that plants transplanted in early June will produce mature tubers that could be harvested during September or early October, around the time of the first vegetation killing frost.

Critical factors for successful sweet potato production include irrigation scheduling and the amount of water to be applied. Irrigation scheduling options rely on the measurement of soil water content or soil water tension. Precise irrigation scheduling by soil water tension criteria is a powerful method to optimize plant performance. By utilizing the ideal soil water tension and adjusting irrigation duration and amount, it is possible to simultaneously achieve high productivity and meet environmental stewardship goals for water use and reduced leaching (Shock and Wang 2011).

Objectives

The overarching goal of this study was to assess the possibility of producing sweet potatoes in eastern Oregon. The specific objectives were to evaluate varieties and develop the irrigation criterion suitable for sweet potato production in eastern Oregon.

Materials and Methods

The field was plowed and disked during fall 2010 and fumigated on February 16, 2011 using metam sodium at 30 gal/acre through sprinklers. The beds (36 inches wide) were formed 3 weeks after fumigation followed by fertilizer to supply 100 lb nitrogen/acre that was shanked into beds. The study followed a split-plot design with irrigation criteria forming the main plots and varieties as subplots with treatments arranged in a randomized complete block. The study had three replications and drip tape was used to deliver irrigation water. Each subplot was 3 beds (9 ft wide) by 30 ft long.

Sweet potato slips were transplanted by hand on June 3 on 30 cm (12-inch) spacing within the row using the drip tape emitter spacing on top of the bed as markers. The drip tape used was Toro Aqua-traxx® 8-mil emitting 8,327 mm/min/30.5 m (0.22 gal/min/100 ft). Slips were transplanted 10 to 15 cm (4 to 6 inch) deep using a hand trowel. Plants were immediately irrigated for 5 hours (0.35 inch) in order to provide soil/transplant contact. Plots were irrigated again on June 4 for 2 hours (0.14 inch). Plants were irrigated again on June 10, 21 and July 5 to provide 0.5 inch of water each. Subsequent irrigations were automatically determined by the datalogger controller, depending on targeted criterion of soil water tension.

The irrigation criteria were 40, 60, 80, and 100 kPa of moisture tension and water was delivered through drip tape. Sweet potato plants in each plot were irrigated automatically and independently when the soil water tension dropped below the targeted irrigation criterion. The irrigation duration was predetermined based on the drip tape capacity to deliver 1.25 cm (0.5 inch) of water in 7 hours and 5 min per incident.

Soil water tension was measured in each main plot with four granular matrix sensors (GMS, Watermark Soil Moisture Sensors Model 200SS, Irrometer Co., Riverside, CA) installed at 20-cm (8-inch) depth in the center of 'Beauregard' rows. Sensors had been calibrated to local soil water tension (Shock et al. 1998). The sensors were connected to a datalogger (CR10X, Campbell Scientific, Logan, UT) through a multiplexer (AM 410 multiplexer, Campbell Scientific, Logan, UT). The datalogger read the sensors and recorded the hourly soil water tension.

The datalogger was programmed to check the sensor readings in each main plot every 12 hours and irrigate the appropriate main plot if the average soil water tension was below the targeted criterion. The irrigations were controlled by the datalogger using a controller (SDM CD16AC controller, Campbell Scientific, Logan, UT) connected to solenoid valves in each main plot. The irrigation water was supplied by a well that maintained a continuous and constant water pressure of 241 kPa (35 psi). The pressure in the drip lines was maintained at 69 kPa (10 psi) by pressure regulators in each main plot. The automated irrigation system was started on July 8 and was turned off on September 29, 2011.

Integrated Pest Management

Preplant herbicides were not used because of the field proximity to sensitive crops. All plots were sprayed with glyphosate 0.86 kg ae/ha (Roundup® at 22 fl oz/acre) on May 26, 2011 to control all emerged weeds prior to transplanting. Sethoxydim (Poast®) at 0.214 kg ai/acre (16 fl oz/acre) plus nonionic surfactant (0.25% v/v) was applied on June 27, 2011 to control grassy weeds. Plots were hand-weeded on June 27 and July 28, 2011 to remove all broadleaf weeds. Later weed cohorts were sparsely distributed and were periodically removed by hand.

Sweet potato vines were flailed on October 4 and roots were dug using a 2-row digger set at 45-cm (18-inch) depth. Roots were picked by hand from the center row and later graded following California standards (May and Scheuerman 1998). In summary, the roots were graded based on California standards: U.S. No.1 were of uniform size, 4.4 to 9 cm (1.75 to 3.5 inches) in diameter and 7.5 to 23 cm (3 to 9 inches) long; U.S. No. 2 (mediums) included misshapen tubers and with a minimum diameter of 4 cm (1.5 inches); Jumbo weighed more than 567 g (20 oz) and was true to type.

The data were subjected to analysis of variance using PROCGLM procedure in Statistical Analysis Software (SAS) and means were compared using Fisher's protected least significant difference procedure at $P \leq 0.05$.

Results and Discussion

The average soil water tension increased with the increase in the targeted irrigation criterion (Table 1). The total amount of water applied from transplanting to harvest includes the water used during the plant establishment phase (June 3 to July 8) and daily rainfall. Total amount of water decreased with the increase in the targeted soil water tension. Sweet potato irrigated at the 40 kPa criterion received a seasonal total of 357.8 mm (14.1 inches) of water compared to 146.1 mm (5.8 inches) at 100 kPa. The water use efficiency (ton/acre marketable yield per inch of water applied) reflected the total amount of water used, which was directly related to the irrigation frequency needed to maintain the targeted irrigation criterion (Fig. 1).

Percent vegetative ground cover at 49 days after transplanting (July 22) was not influenced by the different irrigation criteria (Table 2). Differences in average percent ground cover were related to varietal characteristics. Ground cover for 'Covington' and 'Diane' averaged 80 and 83 percent, respectively, compared to 94 percent for Beauregard and 'Evangeline'. These results are supported by the average runner length for different varieties on July 22 (Table 2). Covington and Diane had shorter runners (51 and 39 cm; 20 and 15 inches) compared to Beauregard and Evangeline, which averaged 89 cm (35 inches).

The number of sweet potato runners per hill at 117 days after transplanting (September 28) was similar among irrigation criteria (Table 3); however, there were differences in the number of runners per hill that were attributed to varieties. Covington and Beauregard averaged 8 and 9 runners, compared to 11 and 12 for Evangeline and Diane, respectively. Beauregard had the longest average runner length at 379 cm (149 inches) and Diane had the shortest at 165 cm (65 inches).

Sweet potato yield varied among irrigation criteria and varieties (Table 4). The highest marketable yields were obtained when plants were irrigated at 40 kPa of moisture tension. There was a gradual decline in root yield with the increase in the targeted soil water tension to trigger irrigation. All varieties produced much lower yield at 80 and 100 kPa. Previous studies by May and Scheuerman (1998) indicated improved yield when sweet potatoes were irrigated at 25 kPa throughout the season or 25 kPa during plant development and 100 kPa during the root bulking stage. It is important to note that the irrigation criterion will be influenced by the soil type. Because the varieties responded similarly to irrigation at 80 and 100 kPa, the irrigation criteria could be changed to 25, 40, 60, and 80 kPa in future studies.

The results indicated that sweet potatoes could be grown successfully in eastern Oregon. Varietal differences in terms of growth habits and yield in response to available moisture were noted. Subsequent studies could help to determine the best variety and irrigation criterion and confirm the preliminary results. We believe the positional placement of irrigation water with drip irrigation may have reduced the weed pressure that would be expected with furrow or overhead irrigation.

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May, D., and B. Scheuerman. 1998. Sweet potato production in California. Vegetable Research Information Center Vegetable Production Series, University of Calif., Division of Agricultural Natural Resources Publ:7237.

Table 1. Average hourly soil water tension, total water applied, marketable yield, and water use efficiency (ton/ha marketable yield per mm of water applied) for sweet potato exposed to four irrigation treatments, Malheur Experiment Station, Oregon State University, Ontario, OR, 2011.

Soil water tension	Hourly soil water tension	Total water applied[1]	Marketable yield[2]	Water use efficiency
kPa	kPa	mm	ton/ha	ton/mm
40	27.7	357.8	44.1	0.12
60	44.4	256.2	38.2	0.15
80	48.6	158.8	24.8	0.16
100	58.9	146.1	23.6	0.16
LSD (0.05)	4.2	40.3	3.1	0.02

[1] Total applied water for each criterion includes the amount applied uniformly to all treatments during plant establishment phase (37.8 mm) and rainfall from June 3 to September 29, 2011 (27.9 mm). 25.4 mm = 1 in.

[2]1 metric ton/ha is equivalent to 892 lb/acre.

Table 2. Sweet potato vegetative percent ground cover and average runner length on July 22 (49 days after transplanting) in response to differential irrigation criteria at Malheur Experiment Station, Ontario, OR, 2011.

Irrigation criterion	Percent ground cover				Average runner length			
	Covington	Beauregard	Evangeline	Diane	Covington	Beauregard	Evangeline	Diane
(kPa)	%				cm			
40	88	95	94	83	56	107	91	43
60	75	93	94	83	48	84	79	33
80	82	93	93	83	51	81	86	38
100	75	94	93	80	48	89	86	41
LSD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS
Average[1]	80 b	94 a	94 a	83 b	51 b	91 a	86 a	39 b

[1] Because there was no significant difference among irrigation criteria, the means among water tension were used to compare variety performance. Average values within a row and group followed by the same letter are not significantly different according to LSD 0.05%.

Table 3. Number of sweet potato runners per hill and average length (cm) on September 28 (117 days after transplanting) in response to differential irrigation criteria at Malheur Experiment Station, Ontario, OR, 2011.

Irrigation criterion	Number of runners/hill				Average length/runner			
	Covington	Beauregard	Evangeline	Diane	Covington	Beauregard	Evangeline	Diane
(kPa)	Number				cm			
40	6	9	9	11	224	452	358	198
60	6	9	10	12	213	399	340	175
80	13	10	12	12	145	348	262	158
100	5	8	11	12	175	315	226	130
LSD (0.05)	NS	NS	NS	NS	36	36	36	91
Average[1]	8 b	9 b	11 a	12 a	191 c	379 a	297 b	165 c

[1] Because there was no significant difference among irrigation criteria, the means among water tension were used to compare variety performance. Average values within a row and group followed by the same letter are not significantly different according to LSD 0.05%.

Table 4. Sweet potato yield and grade in response to differential irrigation criteria and variety at Malheur Experiment Station, Oregon State University, Ontario, OR, 2011.

Irrigation criterion	Sweet potato yield[1] Total	Marketable	U.S. No. 2	U.S. No. 1	Jumbo	Discard[2]
(kPa)	(tons/ha)[3]					
	Beauregard					
40	54.2	49.4	9.7	34.6	5.1	4.8
60	51.6	47.1	8.7	32.8	5.6	4.5
80	38.2	32.2	6.5	22.4	3.4	6.0
100	33.2	27.8	6.6	20.8	0.4	5.4
Average	44.3	39.1	7.9	27.6	3.6	5.2
	Covington					
40	53.6	41.4	15.9	24.5	1.0	12.2
60	42.2	31.1	13.0	17.7	0.4	11.1
80	31.8	16.8	9.5	7.3	0.0	15.1
100	30.4	15.0	6.4	8.6	0.0	15.4
Average	39.5	26.1	11.2	14.5	0.4	13.4
	Diane					
40	49.5	43.0	5.5	35.1	2.4	6.5
60	42.3	38.3	5.5	31.0	1.8	4.0
80	34.2	29.1	6.4	21.3	1.3	5.2
100	32.8	29.0	4.8	21.2	3.0	3.8
Average	39.7	34.8	5.6	27.2	2.1	4.9
	Evangeline					
40	48.6	42.6	7.5	32.0	3.1	6.0
60	41.3	36.5	6.9	27.9	1.7	4.9
80	27.1	21.3	5.7	14.1	1.5	5.9
100	28.5	22.7	5.5	14.4	2.7	8.3
Average	36.4	30.8	6.4	22.1	2.3	5.6
LSD (0.05)						
Irrigation	2.7	3.1	1.3	3.1	1.2	1.3
Variety	2.7	3.1	1.4	3.1	1.3	1.4
Irrigat. X Variety	NS	NS	2.2	NS	NS	NS

[1] Sweet potato grades were based on California standards: U.S. No.1 were of uniform size, 4.4 to 9 cm (1.75 to 3.5 inches) in diameter and 7.5 to 23 cm (3 to 9 inches) long; U.S. No. 2 (mediums) included misshapen tubers and with a minimum diameter of 4 cm (1.5 inches); Jumbo weighed more than 567 g (20 oz) and were true to type.
[2] Discarded roots were <3.8 cm (<1.5 inches) in diameter.
[3] 1 metric ton/ha is equivalent to 892 lb/acre.

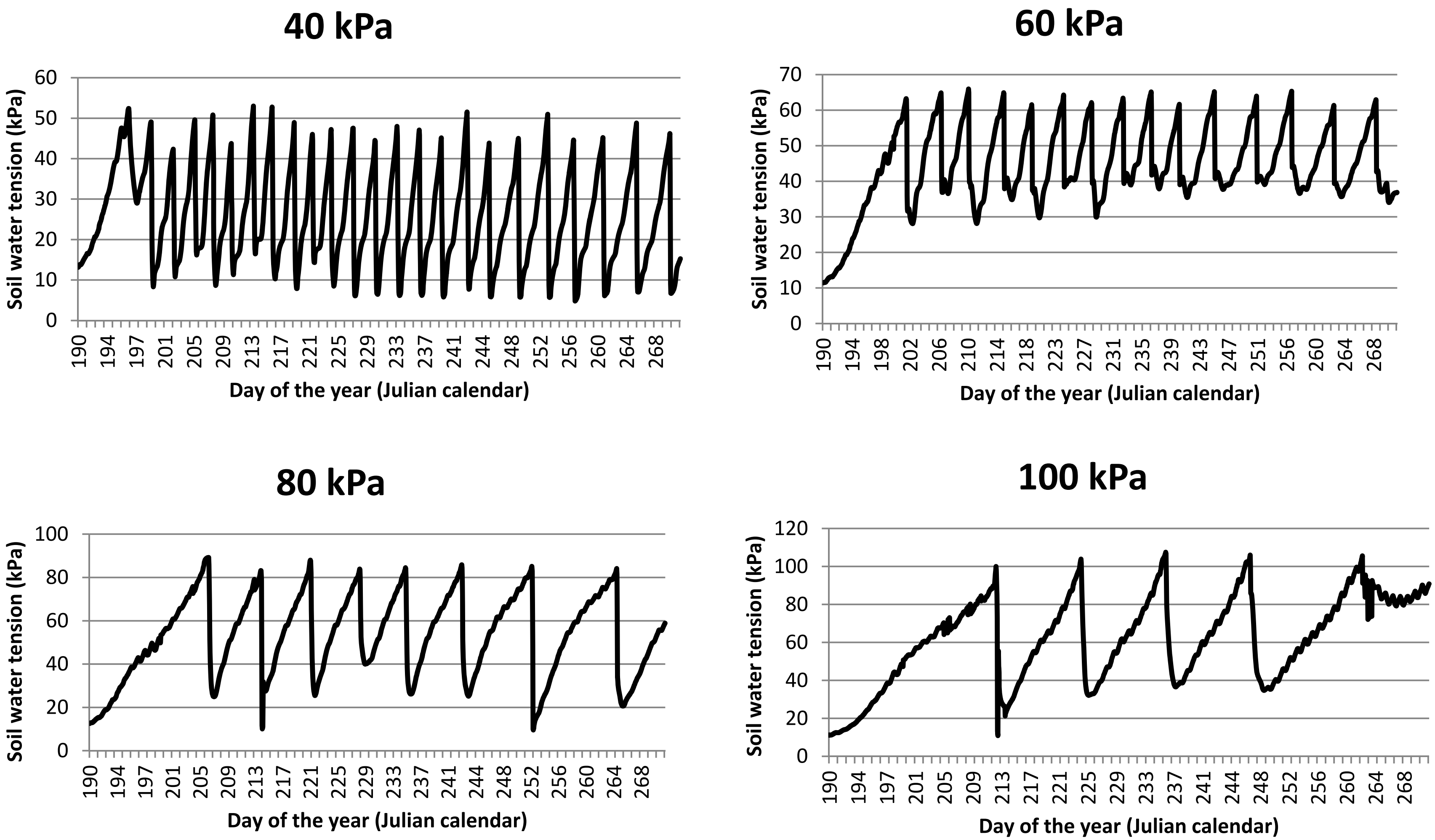

Figure 1. Soil water tension at 17.8-cm (7-inch) depth over time for sweet potato production at Malheur Experiment Station, Oregon State University, Ontario, OR, 2011. Each peak represents 1.25 cm (0.5 inch) of water delivered by drip irrigation with different irrigation criteria.

CONTROL OF YELLOW NUTSEDGE WITH EFFECTIVE CROP ROTATIONS

Joel Felix and Joey Ishida, Malheur Experiment Station, Oregon State University, Ontario, OR, 2011

Introduction

There are relatively fewer herbicides registered for weed management in many specialty crops compared to agronomic crops. Consequently, growers often take advantage of the wider array of herbicides available for use in agronomic crops grown in rotation to manage weed species that are difficult to control in vegetable crops. Yellow nutsedge has become a major weed problem in many agricultural fields in the Treasure Valley of eastern Oregon and southwestern Idaho. The severity of damage and negative effects of yellow nutsedge are especially noticeable when fields are planted to direct-seeded onions. Surveys have indicated an average of 42 percent loss of onion yield in fields heavily infested with yellow nutsedge.

Control of yellow nutsedge presents a challenge because of its ability to reproduce by rhizomes and tubers that are able to survive in the soil for 3 to 4 years. Farming activities, particularly tillage and irrigation, play a significant role in yellow nutsedge distribution in infested fields. Therefore, successful control of yellow nutsedge in the Treasure Valley will require integrated approaches including effective crop rotations and use of herbicides with proven efficacy in every crop grown in a rotation. The objective of this study was to evaluate the effect of tillage, crop rotation, and herbicides on yellow nutsedge control in years preceding onion.

Materials and Methods

The study was initiated in 2007 in a field heavily infested with yellow nutsedge near the Malheur Experiment Station, Ontario, Oregon. The study was a split-plot design with tillage (reduced and conventional) forming the main plots onto which three crop rotations and herbicide treatments were imposed as subplots. Each year the crops were planted on 22-inch beds. The rotations were designed so that the terminal crop would be onion in 2011. Rotations were: 1) corn/corn/sugar beet/wheat/onions; 2) corn/sugar beet/corn/wheat/onions; and 3) corn/corn (late planting)/pinto bean/wheat/onions. The treatments used in each crop are presented in Table 1.

Conventionally tilled plots were moldboard plowed each year and groundhogged twice before forming beds to facilitate furrow irrigation. Reduced-tillage plots were disked only twice to avoid deep tillage, which is believed to redistribute tubers within the soil profile. Fertilizer was applied to provide nutrients as determined by soil tests and using University recommendations in 2007–2010. In 2007, the entire study was planted to Dekalb Roundup Ready® (RR) corn hybrid DK-51-39 with seeds spaced 7 inches within the row. Rotational crops in 2008 were RR corn hybrid DK C52-59 planted on May 15 and RR sugar beet variety (Beta CT 01RR07) planted on April 18. Rotational crops in 2009 were RR corn hybrid DKC 52-59, RR sugar beet BTS 26RR14, and pinto bean variety ‘Othello’. Corn and sugar beet were mechanically planted in respective plots at 7 inches spacing within the row and 6 seeds/ft of row, respectively. Pinto beans were seeded at 80 lb/acre. The entire study area was planted to winter wheat during fall 2009.

Counter® 15-G insecticide was banded over the sugar beet rows at 7.4 lb/acre (terbufos at 1.11 lb ai/acre) immediately after planting. Sugar beet rows were sidedressed with Temik® 15G at 10 lb/acre (aldicarb at 1.5 lb ai/acre) 53 days after planting. Sugar beet and pinto beans were treated with Quadris® at 4 oz/acre (azoxystrobin + chlorothalonil at 2.75 oz ai/acre) on May 22 and June 11 as a preventive measure against rhizoctonia. Sugar beets were thinned on May 28, 2008 to 8-inch spacing within the row. Weeds in wheat were controlled using Bronate® Advanced (bromoxynil + MCPA) herbicide in 2010.

Wheat stubble was flailed immediately after harvest in 2010 and the plots were moldboard plowed and disked or only disked as practiced in previous years. The field was bedded on 22-inch spacing on November 1, 2010. The beds were harrowed down and onion variety 'Vaquero' was planted on April 4, 2011. Lorsban® 15G insecticide was applied at 3.7 oz/1,000 ft of row (chlorpyrifos at 0.101 lb ai/acre) on April 18. The list of herbicides used in each treatment in 2011 is presented in Table 2. Movento® insecticide at 5 fl oz/acre (spirotetramat at 0.078 lb ai/acre) tank-mixed with Pierce (crop oil concentrate) at 1.57 lb ai/acre was applied on June 13 to control onion thrips. Onions were sprayed again for thrips control on June 22 and July 5 using Radiant® at 10 fl oz/acre (spinetoram at 0.078 lb ai/acre) tank-mixed with crop oil at 1 qt/100 gal of water. The final spray for thrips control was on July 24 using Lannate® at 3 pt/acre (methomyl at 0.9 lb ai/acre).

Onion plant tops were flailed on September 8 and bulbs were lifted on September 13 and left on the ground to cure. Bulbs were handpicked from 15 ft of the two center rows on September 20 and graded for quality and yield on September 23, 2011 using USDA standards.

Soil sampling to quantify initial yellow nutsedge tuber density was conducted during spring 2007 after beds were formed and the field irrigated. The process was repeated at the end of each crop year to quantify changes in yellow nutsedge tubers in response to treatments. Five soil cores measuring 4.25 inches in diameter and 12 inches deep each were taken randomly from each subplot. The soil was processed to recover yellow nutsedge tubers using a washing and sieving method. Tubers from each plot were placed in a self-seal plastic bag (ziplock plastic bags) and stored in the dark at 40°F until they were counted and weighed.

Herbicides used on corn in 2007 and rotational crops in 2008–2010 are presented in Table 1. All herbicide treatments were applied using a tractor with a sprayer boom equipped with 8002EVS Teejet nozzles calibrated to deliver 20 gal of solution per acre. The study was furrow irrigated as needed on a calendar schedule to maintain moisture in the top 12 inches of the soil profile. Crops were harvested for yield at maturity from 20 ft of the two center rows of each subplot. The data were subjected to analysis of variance and means were compared using LSD at $P = 0.05$.

Results and Discussion

Yellow nutsedge tubers were relatively uniformly distributed across the field at the beginning of the study in 2007 (Table 3). The herbicide treatments in 2007 reduced the yellow nutsedge tuber population density relative to the untreated control. Because there was no significant difference between tillage for yellow nutsedge tuber population density in 2007, the average is presented in Table 3. Conventional tillage provided the greatest yellow nutsedge tuber reduction from 2008 to 2010 regardless of the crops used in the rotation (Table 3). Yellow nutsedge population density dramatically increased in the untreated treatment in 2008 and 2009 relative to plots treated with herbicides. Interestingly, the number of tubers in the untreated control was reduced by the winter wheat in 2010. Even though the reduction was not as high as that provided by the herbicide treatments in the same year, it is consistent with the fact that yellow nutsedge does not tolerate shading that is provided by fall-planted winter wheat.

The list of herbicides used in each treatment to control weeds in onion in 2011 is presented in Table 2. There was a dramatic increase in yellow nutsedge tubers at the end of 2011, reflecting the inability of onions to compete with yellow nutsedge (Table 3). The highest increase in yellow nutsedge tubers was observed in reduced tillage plots. These results indicate that conventional tillage was best suited to manage yellow nutsedge in onion-based crop rotations.

Yellow nutsedge control in onion averaged greater than 90 percent across herbicide treatments within the conventional tillage system compared to the untreated control (Table 4). Control was 57 to 78 percent for onions grown under the reduced tillage system. These results further demonstrate that yellow nutsedge was best controlled under conventional tillage.

At the conclusion of the 2010 cropping season, the conventionally tilled corn/corn/sugar beet/wheat rotation resulted in the lowest average yellow nutsedge tubers across herbicide treatments (239 tubers/yd^2) compared to 359 and 396 tubers/yd^2 for the corn/sugar beet/corn/wheat and corn/corn/pinto bean/wheat rotations, respectively (Table 3).

The best onion yield was obtained from the conventionally tilled plots (Table 5). Conventionally tilled corn/corn (planted late)/pinto bean/wheat rotation provided the highest marketable onion yield ranging from 1,160 to 1,271 cwt/acre. Onion yield was generally lower in reduced tillage plots regardless of the rotation used.

The results from this study indicate that the greatest yellow nutsedge reduction could be obtained with conventional tillage and the corn/corn/pinto bean/wheat crop rotation. Substituting pinto beans with sugar beet might provide similar benefits if the field did not have a history of rhizoctonia. Rhizoctonia affected sugar beet plant stands and created open patches that allowed yellow nutsedge to grow and produce additional tubers. In heavily infested fields, growing corn for 2 years followed by another crop prior to planting onion would provide the best yellow nutsedge tuber reduction.

Table 1. Yearly list of treatments used in the rotational study to control yellow nutsedge in different crops at Malheur Experiment Station Ontario, OR, 2007-2010.

2007[a]
Conventional and reduced tillage
Corn
1. Untreated
2. Dual II Magnum 1.67 pt/acre (PRE); followed by Roundup 32 fl oz/acre (POST) + AMS 3.2 pt/acre
3. Dual II Magnum 1.67 pt/acre (PRE); followed by Dual II Magnum 1.67 pt/acre (POST) + Roundup 32 fl oz/acre + AMS 3.2 pt/acre
4. Dual II Magnum 2.5 pt/acre (PRE); followed by Basagran 1.5 pt/acre (POST) + Roundup 32 fl oz/acre + AMS 3.2 pt/acre
5. Dual II Magnum 3 pt/acre (PRE); followed by Basagran 2 pt/acre (POST) + Roundup 32 fl oz/acre + AMS 3.2 pt/acre

2008		
Rotational crops in conventional and reduced tillage		
Corn	**Sugar beet**	**Corn (late)**
Untreated	Untreated	Untreated
Roundup 22 oz/acre (POST1) + AMS 3.2 pt/acre Roundup 22 oz/acre (POST2) + AMS 3.2 pt/acre	Roundup 22 oz/acre (POST1) + AMS 3.2 pt/acre Roundup 22 oz/acre (POST2) + AMS 3.2 pt/acre	Eptam 4.5 pt/acre (PPI) Roundup 22 oz/acre (POST1) + AMS 3.2 pt/acre Roundup 22 oz/acre (POST2) + AMS 3.2 pt/acre
Outlook 14 oz/acre (PPI) Roundup 22 oz/acre (POST1) + AMS 3.2 pt/acre Roundup 22 oz/acre (POST2) + AMS 3.2 pt/acre	Nortron 12 oz/acre (PPI) Roundup 22 oz/acre (POST1) + AMS 3.2 pt/acre Roundup 22 oz/acre (POST2) + Eptam 3.5 pt/acre (POST2) + AMS 3.2 pt/acre	Outlook 14 oz/acre (PPI) Roundup 22 oz/acre (POST1) + AMS 3.2 pt/acre Roundup 22 oz/acre (POST2) + AMS 3.2 pt/acre
Eradicane 6 pt/acre (PPI) Roundup 22 oz/acre (POST1) + Basagran 1.5 pt/acre + AMS 3.2 pt/acre Roundup 22 oz/acre (POST2) + AMS 3.2 pt/acre	Outlook 21 oz/acre (PPI) Roundup 22 oz/acre (POST1) + AMS 3.2 pt/acre Roundup 22 oz/acre (POST2) + Nortron 12 oz/acre (POST2) + AMS 3.2 pt/acre	Dual II Magnum 1.33 pt/acre (PPI) Roundup 32 oz/acre (POST1) + Basagran 1.5 pt/acre + AMS 3.2 pt/acre Roundup 22 oz/acre (POST2) + AMS 3.2 pt/acre
Outlook 18 oz/acre (PPI) Roundup 22 oz/acre (POST1) + Basagran 2 pt/acre + AMS 3.2 pt/acre Roundup 22 oz/acre (POST2) + Dual II Magnum 1.33 pt/acre + AMS 3.2 pt/acre	Dual II Magnum 1.33pt/acre (POST1) +Roundup 22 oz/acre (POST1) + AMS 3.2 pt/acre Dual II Magnum 1.33pt/acre (POST2) Roundup 22 oz/acre (POST2) + AMS 3.2 pt/acre	Dual II Magnum 1.33 pt/acre (PPI) Eptam 4.5 pt/acre (PPI) Roundup 32 oz/acre (POST1) + Basagran 1.5 pt/acre + AMS 3.2 pt/acre Roundup 22 oz/acre (POST2) + AMS 3.2 pt/acre

[a] All plots were planted to corn in 2007. Conventional and reduced tillage plots were sprayed with the same herbicide rates as indicated for each year. The main plots were divided into three plots and the rotational crops planted as shown in 2008 and 2009.

Table 1. continued

2009		
Rotational crops in conventional and reduced tillage		
Sugar beet	**Corn**	**Pinto beans**
1. Untreated	Untreated	Untreated
2. Roundup 22 oz/acre (POST1) + Outlook 21 oz/acre (POST1) + AMS 3.2 pt/acre Roundup 22 oz/acre (POST2) + AMS 3.2 pt/acre	Roundup 22 oz/acre (POST1) + AMS 3.2 pt/acre Roundup 22 oz/acre (POST2) + AMS 3.2 pt/acre	Outlook 21 oz/acre (PPI) Raptor 4 oz/acre (POST) + Basagran 0.75 pt/acre + AMS 3.2 pt/acre
3. Roundup 22 oz/acre (POST1) + Outlook 10.5 oz/acre + AMS 3.2 pt/acre	Outlook 21 oz/acre (PPI) Roundup 22 oz/acre (POST1) + AMS 3.2 pt/acre Roundup 22 oz/acre (POST2) + AMS 3.2 pt/acre	Outlook 14 oz/acre (PPI) Outlook 7 oz/acre (POST1) + Basagran 0.75 pt/acre + AMS 3.2 pt/acre Basagran 1.5 pt/acre (POST2) + AMS 3.2 pt/acre
4. Roundup 21 oz/acre (POST1) + Outlook 21 oz/acre + AMS 3.2 pt/acre Roundup 21 oz/acre (POST2) + Nortron 5 oz/acre + AMS 3.2 pt/acre Roundup 22 oz/acre (POST3) + AMS 3.2 pt/acre	Dual II Magnum 1.5 pt/acre (PPI) Roundup 22 oz/acre (POST1) + Basagran 2 pt/acre + AMS 3.2 pt/acre Roundup 22 oz/acre (POST2) + AMS 3.2 pt/acre + AMS 3.2 pt/acre	Dual Magnum 1.33 (PPI) Basagran 1 pt/acre (POST1) + Raptor 4 oz/acre + AMS 3.2 pt/acre Basagran 1.5 pt/acre (POST2) + AMS 3.2 pt/acre
5. Roundup 22 oz/acre (POST1) + Outlook 21 oz/acre (POST1) + AMS 3.2 pt/acre Roundup 22 oz/acre (POST2) + Dual Mag 1.33 pt/acre (POST2) + AMS 3.2 pt/acre Roundup 22 oz/acre (POST3) + AMS 3.2 pt/acre	Dual II Magnum 1.5 pt/acre (PPI) Roundup 22 oz/acre (POST1) + Basagran 2 pt/acre + AMS 3.2 pt/acre Roundup 22 oz/acre (POST2) + Basagran 1.5 pt/acre + AMS 3.2 pt/acre	Dual Magnum 1.33 (PPI) + Treflan 1.5 pt/acre Basagran 1 pt/acre (POST1) + Outlook 18 oz/acre + AMS 3.2 pt/acre Basagran 2 pt/acre + COC 2 pt/acre

2010[a]		
Conventional and reduced tillage		
Wheat	**Wheat**	**Wheat**
1. Untreated	Untreated	Untreated
2. Bronate Advanced 1.66 pt/acre	Bronate Advanced 1.66 pt/acre	Bronate Advanced 1.66 pt/acre
3. Bronate Advanced 1.66 pt/acre	Bronate Advanced 1.66 pt/acre	Bronate Advanced 1.66 pt/acre
4. Bronate Advanced 1.66 pt/acre	Bronate Advanced 1.66 pt/acre	Bronate Advanced 1.66 pt/acre
5. Bronate Advanced 1.66 pt/acre	Bronate Advanced 1.66 pt/acre	Bronate Advanced 1.66 pt/acre

[a] All wheat plots in 2010 were treated with Bronate Advanced 1.66 pt/acre

Table 2. List of herbicide treatments in 2011 for yellow nutsedge control following 4 years of crop rotation and different tillages at the Malheur Experiment Station, Ontario, OR.

Treatment		Rate lb ai/acre	Application timing	Date
1.	Untreated			
2.	Prowl H2O	0.95	PRE	May 3
	GoalTender + Buctril	0.25 + 0.125	POST	June 9
3.	Prowl H2O fb	0.95	PRE	May 3
	Outlook	0.98	POST	May 25
	GoalTender + Buctril	0.25 + 0.125	POST	June 9
4.	Nortron	0.5	PRE	May 3
	Prowl H2O	0.95	PRE	May 3
	Outlook	0.98	POST	May 25
	GoalTender + Buctril	0.25 + 0.125	POST	June 9
5.	Nortron	0.5	PRE	May 3
	Prowl	0.95	PRE	May 3
	Outlook	0.98	POST	May 25
	GoalTender + Buctril	0.25 + 0.125	POST	June 9

Table 3. Yellow nutsedge tuber (numbers/yd^2) changes in response to tillage and herbicide treatments at Malheur Experiment Station Ontario, OR from 2007 to 2010 and following onion in 2011.

	2007	
	Spring	Fall
Treatment[a]	Corn	
	--------- tubers/yd^2 ----------	
1	5,988 a[b]	9,962 a
2	5,146 a	2,197 b
3	5,867 a	2,559 b
4	5,707 a	3,178 b
5	4,274 a	2,155 b

	2008					
	Conventional tillage			Reduced tillage		
Treatment[a]	Corn	Sugar beet	Corn (late)	Corn	Sugar beet	Corn (late)
	tubers/yd^2					
1	11,173 a	15,187 a	8,541 a	14,843 a	20,040 a	8,964 a
2	984 b	1,056 b	966 b	1,431 b	1,412 b	996 b
3	1,129 b	670 b	875 b	1,243 b	990 b	1,630 b
4	1,835 b	1,388 b	1,044 b	1,612 b	1,497 b	1,243 b
5	1,750 b	1,756 b	736 b	1,738 b	911 b	1,038 b
	2009					
	Sugar beet	Corn	Pinto bean	Sugar beet	Corn	Pinto bean
1	17,040 a	14,366 a	10,243 a	13,376 a	24,567 a	13,841 a
2	537 b	773 b	453 b	984 b	990 b	1,008 b
3	869 b	1,086 b	531 b	797 b	881 b	1,014 b
4	917 b	1,195 b	435 b	857 b	1,262 b	954 b
5	392 c	887 b	513 b	972 b	525 c	839 b
	2010					
	Wheat	Wheat	Wheat	Wheat	Wheat	Wheat
1	4,992 a	10,720 a	7,418 a	6,084 a	11,855 a	7,292 a
2	254 b	423 b	447 b	410 b	471 b	954 b
3	175 c	332 b	453 b	338 b	386 b	718 b
4	380 b	314 b	392 b	332 b	598 b	899 b
5	145 c	368 b	290 b	338 b	435 b	592 b
	2011					
	Onion	Onion	Onion	Onion	Onion	Onion
1	15,875 a	18,187 a	15,428 a	15,060 a	18,519 a	16,436 a
2	748 b	2,294 b	1,062 b	1,992 b	2,710 b	2,095 b
3	1,014 b	1,461 b	875 b	2,668 b	2,903 b	1,672 b
4	362 b	1,533 b	561 b	2,179 b	1,274 b	2,239 b
5	290 b	549 c	320 b	1,473 b	1,080 b	1,503 b

[a]Herbicides used in each treatment and year are listed in table 1.
[b]Means within a column with the same letter are not significantly different (LSD, P = 0.05).

Table 4. Yellow nutsedge control in response to different treatments in 2011, Malheur Experiment Station, Ontario, OR.

Treatment[a]	Yellow nutsedge control					
	Corn/corn/sugar beet/wheat		Corn/sugar Beet/corn/wheat		Corn/corn(late)/pinto beans/wheat	
	Conventional	Reduced	Conventional	Reduced	Conventional	Reduced
	----------------- % -----------------		----------------- % -----------------		----------------- % -----------------	
1	0	0	0	0	0	0
2	98	72	90	73	94	78
3	94	57	92	73	93	77
4	94	60	87	68	94	77
5	98	72	93	83	98	78
LSD 0.05	14		14		14	

[a]Treatment names are listed in Table 2.

Table 5. Marketable onion yield in response to different treatments at the Malheur Experiment Station, Ontario, OR, 2011.

	Marketable onion yield							
	Conventional tillage				Reduced tillage			
Treatment[a]	Medium	Jumbo	Col + S Col[b]	Marketable	Medium	Jumbo	Col + S Col	Marketable
	---------- cwt/acre ----------							
	Previous crops: corn/corn/sugar beet/wheat							
1	81	1	7	89	39	1	0	41
2	217	779	41	1,036	151	710	16	877
3	218	813	41	1,072	151	720	79	950
4	157	936	97	1,190	178	745	21	944
5	259	836	5	1,099	152	742	86	981
LSD 0.05	84	257	73	264	84	257	73	264
	Previous crops: corn/sugar beet/corn/wheat							
1	24	0	0	24	43	3	0	46
2	94	612	111	816	254	606	19	879
3	79	618	140	836	160	808	72	1,040
4	74	695	157	926	189	663	37	889
5	64	578	192	833	162	746	80	988
LSD 0.05	84	257	73	264	84	257	73	264
	Previous crops: corn/corn(late)/pinto beans/wheat							
1	24	0	0	24	64	2	0	66
2	137	1,022	74	1,233	246	542	0	788
3	121	855	125	1,101	222	619	18	858
4	137	1,007	127	1,271	236	700	12	949
5	138	880	142	1,160	228	725	52	1,005
LSD 0.05	84	257	73	264	84	257	73	264

[a] Treatment names are listed in Table 2 above.
[b] Col + S Col = Colossal and Super Colossal onion sizes.