CONTROL OF YELLOW NUTSEDGE WITH EFFECTIVE CROP ROTATIONS

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Introduction

Yellow nutsedge was first reported as a weed in the southwestern United States in 1889 (Defelice 2002). It is an introduced invasive weed that has become naturalized within the United States. Diversification of crops within a rotation may provide effective management of yellow nutsedge and avoid expansion into new fields.

Yellow nutsedge is increasingly becoming a major crop production threat in many agricultural fields in the Treasure Valley of eastern Oregon and southwestern Idaho. The severity and negative effects of yellow nutsedge is especially noticeable when fields are planted to direct-seeded onions. A grower field survey conducted by Ransom et al. (2003) indicated that onion yield reductions averaged 42 percent in heavily infested fields. 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 many years. Research results at the Malheur Experiment Station indicate that millions of tubers are produced per unit area each season (Shock et al. 2006, Felix and Ishida 2007, 2008). Farming activities play a significant role in yellow nutsedge distribution in infested fields (Schippers et al. 1993). Successful control of yellow nutsedge will require integrated approaches including effective crop rotations and use of herbicides with proven efficacy. This study is a first step in developing crop rotation programs to demonstrate the positive contributions of extended rotations on yellow nutsedge control.

Materials and Methods

A multi-year 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 while rotational crops and herbicide treatments served as subplots. The rotations are designed so that the terminal crop in each rotation will be onion. Rotations are: (1) corn/corn/sugar beet/wheat/onions; (2) corn/sugar beet/corn/wheat/onions; and (3) corn/corn (late planting)/pinto bean/wheat/onions.

Conventionally tilled plots were moldboard plowed each year and disked twice before forming beds to facilitate furrow irrigation. Reduced-tillage plots were disked only twice to avoid deep tillage, which is believed to distribute tubers within the soil profile. Following soil analysis, a compound fertilizer to provide 120 lb nitrogen (N), 30 lb phosphorus (P), 13 lb sulfate, 2 lb zinc (Zn), and 1 lb boron (B) per acre was applied on

May 4, 2007. In 2008, plots were fertilized with a compound fertilizer to provide 180 lb/acre N, 20 lb/acre potassium (K), and 3 lb/acre Zn on June 16, 2008. The field was fertilized to provide 175 lb/acre N (urea) and 2 lb/acre Zn in 2009. Each year the crops were planted on 22-inch beds. 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 'Othello' pinto beans. Corn and sugar beet were mechanically planted in respective plots at 7 inches within the row and 8 seeds per ft of row, respectively. Pinto beans were seeded at 80 lb/acre. Counter® 15-G insecticide was banded over the sugar beet rows at 7.4 lb/acre immediately after planting. Sugar beet rows were sidedressed with aldicarb 1.5 lb ai/acre (Temik® 15G at 10 lb/acre) 53 days after planting. Sugar beet and pinto beans were sprayed with azoxystrobin + chlorothalonil at 2.75 oz ai/acre (Quadris® at 4 oz/acre) on May 22 and June 11, respectively. Sugar beets were thinned on May 28, 2008 to 8-inch spacing within the row.

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 monitor yellow nutsedge tuber changes in response to treatments. Five soil cores measuring 4.25 inches in diameter and 12 inches deep each were taken randomly from each plot. The soil was processed to recover yellow nutsedge tubers using the washing and sieving procedure. Tubers from each plot were placed in a ziplock plastic bag and stored in the dark at 40°F until they were counted and weighed. 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 plot.

Herbicides used on corn in 2007 in each treatment were (1) untreated, (2) s-metolachlor at 1.6 lb ai/acre (Dual Magnum® at 1.67 pt/acre) pre-emergence (PRE), (3) Dual Magnum at 1.67 pt/acre PRE followed by 1.67 pt/acre postemergence (POST), (4) Dual Magnum at 2.5 pt/acre plus bentazon 0.75 lb ai/acre (Basagran® at 1.5 pt/acre) (PRE), and (5) Dual Magnum at 3 pt/acre plus Basagran at 2 pt/acre (PRE). Treatments 2-5 were followed by two sequential POST applications of glyphosate at 1.13 lb ae/acre (Roundup Original Max® at 32 fl oz/acre) plus ammonium sulfate (AMS). Treatments used in 2008 are presented in Table 1. All PRE herbicide treatments were applied on May 13, 2008, using a tractor with a sprayer boom equipped with 8002EVS Teejet nozzles calibrated to deliver 20 gal of solution per acre. The sugar beet plots were sidedressed with aldicarb at 1.5 lb ai/acre (Temik 15-G at 10 lb/acre) on June 3, 2008 to control sugar beet root maggot and beds were recorrugated. POST herbicide treatments were applied on June 10 and June 25, 2008 using a tractor as described above. Evaluation of sugar beet plots on June 30, 2008 indicated plant wilt and sudden death, which was characteristic of rhizoctonia infestation. Sugar beet plants were treated with azoxystrobin + chlorothalonil at 2.75 oz ai/acre (Quadris Opti® at 4 fl oz/acre) in 2009 as a preventive measure against the disease. The 2009 herbicide treatments are contained in Tables 2-7.

All plots were furrow irrigated on a calendar schedule to maintain moisture in the top 12-inch soil profile. Sugar beet plots were sprayed with recommended preventive fungicides and insecticides using an aircraft during August through September of each year. The sugar beet plants were flailed and harvested in October, while corn and pinto beans were hand harvested. The data were subjected to analysis of variance and the means compared using Fisher's protected LSD at P = 0.05.

Results and Discussion

The study area had a relatively uniform distribution of yellow nutsedge tubers/ft^2 at the initiation of the study (Table 1). There was no difference in corn yield between treatments except for the untreated control that had very low yield due to excessive weed competition (Table 1). There was no difference between tillage treatments for corn yield, which averaged 5 and 5.7 tons/acre for conventional and reduced tillage, respectively.

Soil core samples taken during fall 2007 indicated significant reduction in the number of tubers in response to herbicide treatments (data not shown). There was no difference in the number of yellow nutsedge tubers between conventional- and reduced-till plots. This was expected because tillage effects do not manifest themselves until at least 4 years into the rotations (Singh et al. 1997). Soil sampling during fall 2007 indicated a trend for reduced tuber numbers in plots treated with sequential Dual Magnum at 1.67 pt/acre followed by Roundup Original Max at 32 fl oz/acre. Plots treated with Dual Magnum at 1.67 pt/acre followed by a combination of Roundup plus Basagran at 1.5 pt/acre did not improve yellow nutsedge control.

Details of treatments for crops grown in 2008 are presented in Table 2. Soil core samples taken during fall 2008 indicated a continued decline in yellow nutsedge tubers both in conventional- and reduced-till plots (Tables 3-5). Samples taken during fall 2009 indicated significant drop in yellow nutsedge tubers in response to crop rotation and herbicide treatments (Tables 3-5). Similarly, visual evaluations on July 13, 2009 indicated better yellow nutsedge control with different weed control programs. A combination of herbicide treatments and crop sequence suggest better yellow nutsedge control, especially in conventionally tilled plots.

In 2009, percent sugar content ranged from 17.1 to 17.6 percent and was significantly reduced in the untreated control (Table 6). However, sugar beet root yield was significantly greater in conventionally tilled treatments. The root yield ranged from 21.9 to 24.5 ton/acre with conventional tillage compared to 16.4 to 18.5 ton/acre for reduced tilled treatments. Concomitantly, the estimated recoverable sugar was greater for conventionally tilled (6,363 to 7,297 lb/acre) and significantly lower (4,892 to 5,534 lb/acre) in reduced-till plots. Sugar beet yield and estimated recoverable sugar was lowest in the untreated control due to excessive weed pressure.

Corn yield was similar across tillage and ranged from 201 to 236 bu/acre (Table 7). Corn yield was significantly reduced in the untreated control, which was 125 and 104

bu/acre in conventional and reduced tillage treatments, respectively.

Pinto bean yield was relatively better with conventional tillage (0.9 to 1.3 ton/acre) compared to 0.7 to 0.9 ton/acre with reduced tillage (Table 8). The yield was very low in the untreated control plots, 0.5 and 0.2 ton/acre for conventional and reduced tillage, respectively.

Conclusion

Crop rotation and herbicide treatments seem to have dramatically reduced the number of yellow nutsedge tubers. Planting corn may provide the best yellow nutsedge reduction. Establishment of sugar beet and pinto beans was affected by the excessive plant residues in the reduced tillage treatments.

References

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Table 1. Yellow nutsedge tuber population density (May 29, 2007) at the initiation of the study and corn yield at the Malheur Experiment Station, Oregon State University, Ontario, OR, summer 2007.

Treatment		Conventional tillage			Reduced tillage		
		Tubers	Tuber weight	Corn yield	Tubers	Tuber weight	Corn yield
		--- ft^{-2} ---	ounces	t/a	--- ft^{-2} ---	Ounces	--- t/acre ---
Untreated		729	2.2	1.2	614	1.9	1.6
Dual II Magnum Roundup OriginalMax Ammonium sulfate	1.67 pt/a 32 fl oz/a 2% V/V	628	2.0	5.4	526	1.9	6.3
Dual II Magnum Dual II Magnum Roundup OriginalMax Ammonium sulfate	1.67 pt/a 1.67 pt/a 32 fl oz/a 2% V/V	641	2.3	5.5	658	2.2	6.1
Dual II Magnum Basagran Roundup OriginalMax Ammonium sulfate	2.5 pt/a 1.5 pt/a 32 fl oz/a 2% V/V	649	2.1	6.3	631	2.1	5.4
Dual II Magnum Basagran Roundup OriginalMax Ammonium sulfate	3.0 pt/a 2.0 pt/a 32 fl oz/a 2% V/V	529	1.7	6.6	430	1.5	6.5
LSD (P = 0.05)		346	1.0	1.5	346	1.0	1.5

Table 2. The 2008 treatment list for the rotation study to control yellow nutsedge at the Malheur Experiment Station, Ontario, OR, 2008

	Conventional and reduced tillage				Conventional and reduced tillage		
	Corn and corn planted late				Sugar beets		
	Treatment	Rate	Timing[†]		Rate	Timing
1	Untreated			Untreated		
2	Roundup PowerMax	21.3 oz/a	POST 1	Roundup PowerMax	21.3 oz/a	POST 1
	Ammonium Sulfate	0.8 gal/a		Ammonium Sulfate	0.8 gal/a	
	Roundup PowerMax	21.3 oz/a	POST 2	Roundup PowerMax	21.3 oz/a	POST 2
	Ammonium Sulfate	0.8 gal/a		Ammonium Sulfate	0.8 gal/a	
3	Outlook	14 oz/a	PPI	Nortron	2.0 pt/a	PPI
	Roundup PowerMax	21.3 oz/a	POST 1	Roundup PowerMax	21.3 oz/a	POST 1
	Ammonium Sulfate	0.8 gal/a		Ammonium Sulfate	0.8 gal/a	
	Roundup PowerMax	21.3 oz/a	POST 2	Roundup PowerMax	21.3 oz/a	POST 2
	Ammonium Sulfate	0.8 gal/a		Eptam EC	3.5 pt/a	POST 2
				Ammonium Sulfate	0.8 gal/a	
4	Eradicane	6 pt/a	PPI	Outlook	21 oz/a	POST 1
	Roundup PowerMax	21.3 oz/a	POST 1	Roundup PowerMax	21.3 oz/a	POST 1
	Basagran	1.5 pt/a	POST 1	Ammonium Sulfate	0.8 gal/a	
	Ammonium Sulfate	0.8 gal/a		Roundup PowerMax	21.3 oz/a	POST 2
	Roundup PowerMax	21.3 oz/a	POST 2	Nortron	2.88 fl oz/a	POST 2
	Ammonium Sulfate	0.8 gal/a		Ammonium Sulfate	0.8 gal/a	
5	Outlook	18 oz/a	PPI	Dual Magnum	1.33 pt/a	POST 1
	Roundup PowerMax	21.3 oz/a	POST 1	Roundup PowerMax	21.3 oz/a	POST 1
	Basagran	2.0 pt/a	POST 1	Ammonium Sulfate	0.8 gal/a	
	Ammonium Sulfate	0.8 gal/a		Roundup PowerMax	21.3 oz/a	POST 2
	Roundup PowerMax	21.3 oz/a	POST 2	Dual Magnum	1.33 pt/a	POST 2
	Dual Magnum	1.33 pt/a	POST 2	Ammonium Sulfate	0.8 gal/a	
	Ammonium Sulfate	0.8 gal/a				

[†] PP I= Pre-plant incorporated (April 17, 2008); POST 1 = Herbicides applied post-emergence (June 6, 2008); POST 2 = Herbicides applied post-emergence (June 26, 2008). All post-emergence treatments included ammonium sulfate.

Table 3. Yellow nutsedge tubers, weight, and percent control in response to tillage, crop rotation, and herbicides used on sugar beet at Malheur Experiment Station, 2008-2009

				Yellow nutsedge[††]				
				Tubers	Weight	Tubers	Weight	Control
Treatment	Rate	Timing[‡]	Code	11/3/2008	11/3/2008	10/23/2009	10/23/2009	7/13/2009
				---- #/yd^2 ----	----oz/yd^2 ---	---- #/yd^2 ----	---oz/yd^2 ---	---- % ----
Conventional tillage								
CONV-TILL/CORN/CORN/SBEET[†] Untreated				11173 c	34.6 c	17040 b	49.3 b	0 g
CONV-TILL/CORN/CORN/SBEET				984 d	4.1 e	537 e	1.8 e	94 abc
OUTLOOK	21 oz/a	POST1	B					
Roundup PowerMax	22 oz/a	POST1	B					
Ammonium Sulfate	0.4 gal/a		B					
Roundup PowerMax	22 oz/a	POST2	C					
Ammonium Sulfate	2.5 % V/V		C					
CONV-TILL/CORN/CORN/SBEET				1129 d	4.4 e	869 e	2.9 e	93 abc
OUTLOOK	10.5 oz/a	POST1	B					
Roundup PowerMax	21.3 oz/a	POST1	B					
Ammonium Sulfate	0.4 gal/a		B					
OUTLOOK	10.5 oz/a	POST2	C					
Roundup PowerMax	21.3 oz/a	POST2	C					
Ammonium Sulfate	0.4 gal/a		C					
CONV-TILL/CORN/CORN/SBEET				1835 d	5.7 e	917 e	2.9 e	94 abc
OUTLOOK	21 oz/a	POST1	B					
Roundup PowerMax	21.3 oz/a	POST1	B					
Ammonium Sulfate	0.4 gal/a		B					
Nortron	5.0 oz/a	POST2	C					
Roundup PowerMax	21.3 oz/a	POST2	C					
Ammonium Sulfate	0.4 gal/a		C					
Roundup PowerMax	21.3 oz/a	POST3	D					
Ammonium Sulfate	0.4 gal/a		D					
CONV-TILL/CORN/CORN/SBEET				1750 d	6.5 e	392 e	1.4 e	94 abc
OUTLOOK	21 oz/a	POST1	B					
Roundup PowerMax	21.3 oz/a	POST1	B					
Ammonium Sulfate	0.4 gal/a		B					
Roundup PowerMax	21.3 oz/a	POST2	C					
Dual Magnum	1.33 pt/a	POST2	C					
Ammonium Sulfate	0.4 gal/a		C					
Nortron	6.0 oz/a	POST3	D					
Roundup PowerMax	21.3 oz/a	POST3	D					
Ammonium Sulfate	0.4 gal/a		D					
Reduced tillage								
REDUCED-TILL/CORN/CORN/SBEET Untreated				14843 b	46.2 ab	13376 cd	36.4 cd	0 g
REDUCED -TILL/CORN/CORN/SBEET				1431 d	5.5 e	984 e	3.4 e	88 a-e
OUTLOOK	21 fl oz/a	POST1	B					
Roundup PowerMax	22 oz/a	POST1	B					
Roundup PowerMax	22 oz/a	POST2	C					
REDUCED -TILL/CORN/CORN/SBEET				1243 d	5.0 e	797 e	3.4 e	92 a-d
OUTLOOK	10.5 oz/a	POST1	B					
Roundup PowerMax	21.3 oz/a	POST1	B					
OUTLOOK	10.5 oz/a	POST2	C					
Roundup PowerMax	21.3 oz/a	POST2	C					
REDUCED -TILL/CORN/CORN/SBEET				1612 d	5.8 e	857 e	3.0 e	87 c-f
OUTLOOK	21 oz/a	POST1	B					
Roundup PowerMax	21.3 oz/a	POST1	B					
Nortron	5.0 oz/a	POST2	C					
Roundup PowerMax	21.3 oz/a	POST2	C					
Roundup PowerMax	21.3 oz/a	POST3	D					
REDUCED -TILL/CORN/CORN/SBEET				1738 d	7.4 e	972 e	3.5 e	87 c-f
OUTLOOK	21 oz/a	POST1	B					
Roundup PowerMax	21.3 oz/a	POST1	B					
Roundup PowerMax	21.3 oz/a	POST2	C					
Dual Magnum	1.33 pt/a	POST2	C					
Nortron	6.0 oz/a	POST3	D					
Roundup PowerMax	21.3 oz/a	POST3	D					

[†]CONV-TILL = Conventional tillage /corn/corn/sbeet = Conventional tillage/corn(2007)/corn(2008)/sugar beet(2009).
[‡]POST1 = post-emergence herbicides on June 18; POST2 = herbicides sprayed on June 23; and POST3 = sprayed on July 2, 2009.
[††]Means within a column with the same letter are not significantly different (LSD, P=0.05)

Table 4. Yellow nutsedge tubers, weight, and percent control in response to tillage, crop rotation, and herbicides used on pinto beans at Malheur Experiment Station, 2008-2009.

					Yellow nutsedge[††]				
					Tubers	Weight	Tubers	Weight	Control
Treatment	Rate		Timing[‡]	Code	11/3/2008	11/3/2008	10/23/2009	10/23/2009	7/13/2009
					--- #/yd^2 ---	----oz/yd^2 ---	---- #/yd^2 ----	---oz/yd^2 ---	---- % ----
Conventional tillage									
CONV-TILL/CORN/CORN(Late)/PBEAN[†] Untreated					8541 c	24.5 d	10243 d	30.8 d	0 g
CONV-TILL /CORN/CORN(Late)/PBEAN					966 d	2.7 e	453 e	1.9 e	96 ab
OUTLOOK	21	oz/a	PPI	A					
+ Raptor	4	oz/a	POST	B					
+ Basagran	12	fl oz/a		B					
Ammonium sulfate	0.4	gal/a		B					
CONV-TILL /CORN/CORN(Late)/PBEAN					875 d	3.1 e	531 e	2.2 e	97 a
OUTLOOK	14	fl oz/a	PPI	A					
OUTLOOK	7	fl oz/a	POST1	B					
+ Basagran	12	fl oz/a		B					
+ Ammonium Sulfate	3.2	pt/a		B					
Basagran	1.5	pt/a	POST2	C					
+ Ammonium Sulfate	0.4	gal/a		C					
CONV-TILL /CORN/CORN(Late)/PBEAN					1044 d	3.8 e	435 e	1.8 e	96 ab
Dual II Magnum	1.33	pt/a	PPI	A					
Basagran	1.0	pt/a	POST	B					
+ Raptor	4	oz/a		B					
+ Ammonium Sulfate	3.2	pt/a		B					
Basagran	1.0	pt/a		C					
+ Ammonium Sulfate	3.2	pt/a		C					
CONV-TILL /CORN/CORN(Late)/PBEAN					736 d	2.7 e	513 e	1.9 e	97 a
Dual II Magnum	1.33	pt/a	PPI	A					
Treflan EC	1.5	pt/a	PPI	A					
Basagran	1	pt/a	POST1	B					
+ OUTLOOK	18	oz/a		B					
+ Ammonium Sulfate	0.4	gal/a		B					
Basagran	2.0	pt/a	POST2	C					
+ Crop Oil Concentrate	2.0	pt/a		C					
Reduced tillage									
RED-TILL/CORN/CORN(Late)/PBEAN Untreated					8964 c	26.1 cd	13841 bc	39.5 c	0 g
R-T/CORN/CORN(Late)/PBEAN					996 d	4.4 e	1008 e	4.0 e	83 def
OUTLOOK	21	oz/a	PPI	A					
Raptor	4	oz/a	POST	B					
+ Basagran	12	fl oz/a		B					
+ Ammonium Sulfate	0.4	gal/a		B					
RED-TILL /CORN/CORN(Late)/PBEAN					1630 d	5.8 e	1014 e	4.1 e	96 abc
OUTLOOK	14	fl oz/a	PPI	A					
OUTLOOK	7	fl oz/a	POST1	B					
+ Basagran	12	fl oz/a		B					
+ Ammonium Sulfate	3.2	pt/a		B					
Basagran	1.5	pt/a	POST2	C					
+ Ammonium Sulfate	0.4	gal/a		C					
RED-TILL /CORN/CORN(Late)/PBEAN					1243 d	4.8 e	954 e	3.6 e	87 c-f
Dual Magnum	1.33	pt/a	PPI	A					
Basagran	1.0	pt/a	POST1	B					
+ Raptor	4	oz/a		B					
+ Ammonium Sulfate	3.2	pt/a		B					
Basagran	1.0	pt/a	POST2	C					
+ Ammonium Sulfate	3.2	pt/a		C					
RED-TILL /CORN/CORN(Late)/PBEAN					1038 d	4.2 e	839 e	3.6 e	92 a-d
Dual II Magnum	1.33	pt/a	PPI	A					
+ Treflan EC	1.5	pt/a	PPI	A					
Basagran	1	pt/a	POST1	B					
+ OUTLOOK	18	oz/a		B					
+ Ammonium Sulfate	0.4	gal/a		B					
Basagran	2.0	pt/a	POST2	C					
+ Crop Oil Concentrate	2.0	pt/a		C					

[†]CONV-TIL = Conventional-tillage; RED-TILL = Reduced tillage /corn/corn(late)/pbean=corn(2007)/corn plated late(2008)/pinto beans(2009).
[‡] PPI = Pre-plant incorporated applied May 13; POST1 = post-emergence herbicides on June 19; POST2 = herbicides on July 2, 2009.
[††]Means within a column with the same letter are not significantly different (LSD, P = 0.05).

Table 5. Yellow nutsedge tubers, weight, and percent control in response to tillage, crop rotation, and herbicides used on corn at Malheur Experiment Station, 2008-2009

Treatment	Rate	Timing[‡]	Code	Yellow nutsedge[††] Tubers 11/3/2008	Weight 11/3/2008	Tubers 10/23/2009	Weight 10/23/2009	Control 7/13/2009
				-- No./yd^2 --	---oz/yd^2 ---	-- No./yd^2 ---	---oz/yd^2 ---	---- % ----
CONV-TILL/CORN/SBEET/CORN[†] Untreated				15187 b	45.9 b	14366 bc	44.1 bc	0 g
CONV-TILL/CORN/SBEET/CORN				1056 d	3.2 e	773 e	2.7 e	82 ef
Roundup PowerMax	21.3 oz/a	POST1	B					
+ Ammonium Sulfate	0.8 gal/a		B					
Roundup PowerMax	21.3 oz/a	POST2	C					
+ Ammonium Sulfate	0.8 gal/a		C					
CONV-TILL/CORN/SBEET/CORN				670 d	2.5 e	1086 e	3.1 e	96 ab
OUTLOOK	21 oz/a	PPI	A					
Roundup PowerMax	21.3 oz/a	POST	B					
+ Ammonium Sulfate	0.8 gal/a		B					
CONV-TILL/CORN/SBEET/CORN				1388 d	4.6 e	1195 e	3.6 e	94 abc
Dual II Magnum	1.5 pt/a	PPI	A					
Roundup PowerMax	21.3 oz/a	POST1	B					
+ Ammonium Sulfate	0.8 gal/a		B					
+ Basagran	2.0 pt/a		B					
Roundup PowerMax	21.3 oz/a	POST2	C					
+ Ammonium Sulfate	0.8 gal/a		C					
CONV-TILL/CORN/SBEET/CORN				1756 d	6.2 e	887 e	2.5 e	96 abc
Dual II Magnum	1.5 pt/a	PPI	A					
Roundup PowerMax	21.3 oz/a	POST1	B					
+ Ammonium Sulfate	0.8 gal/a		B					
+ Basagran	2.0 pt/a		B					
Roundup PowerMax	21.3 oz/a	POST2	C					
+ Basagran	1.5 pt/a		C					
+ Ammonium Sulfate	0.8 gal/a		C					
Reduced tillage								
REDUCED-TILL/CORN/SBEET/CORN Untreated				20040 a	56.1 a	24567 a	68.1 a	0 g
REDUCED -TILL/CORN/SBEET/CORN				1412 d	5.4 e	990 e	4.0 e	78 f
Roundup PowerMax	21.3 oz/a	POST	B					
Roundup PowerMax	21.3 oz/a	POST	C					
REDUCED -TILL/CORN/SBEET/CORN				990 d	3.9 e	881 e	3.6 e	91 a-e
OUTLOOK	21 oz/a	PPI	A					
Roundup PowerMax	21.3 oz/a	POST	B					
REDUCED -TILL/CORN/SBEET/CORN				1497 d	5.7 e	1262 e	5.0 e	87 b-f
Dual II Magnum	1.5 pt/a	PPI	A					
Roundup PowerMax	21.3 oz/a	POST1	B					
+ Ammonium Sulfate	0.8 gal/a		B					
+ Basagran	2.0 pt/a		B					
Roundup PowerMax	21.3 oz/a	POST2	C					
+ Ammonium Sulfate	0.8 gal/a		C					
REDUCED -TILL/CORN/SBEET/CORN				911 d	4.5 e	525 e	2.1 e	96 ab
Dual II Magnum	1.5 pt/a	PPI	A					
Roundup PowerMax	21.3 oz/a	POST1	B					
+ Ammonium Sulfate	0.8 gal/a		B					
+ Basagran	2.0 pt/a		B					
Roundup PowerMax	21.3 oz/a	POST2	C					
+ Basagran	1.5 pt/a		C					
+ Ammonium Sulfate	0.8 gal/a		C					

[†]CONV-TILL = Conventional tillage; /corn/sbeet/corn = /corn (2007)/sugar beet (2008)/corn (2009).
[‡] PPI = Pre-plant incorporated applied May 13; POST1 = post-emergence herbicides on June 18; POST2 = herbicides on June 23, 2009.
[††]Means within a column with the same letter are not significantly different (LSD, P = 0.05).

Table 6. Sugar beet yield in response to tillage and herbicides at the Malheur Experiment Station, Ontario, OR, 2008-2009.

				Sugar beet yield[††]		
Treatment	Rate	Timing[‡]	Code	Sugar content 10/9/2009	Sugar yield	Estimated Rec Sugar
				%	ton/acre	lb/acre
CONV-TILL/CORN/CORN/SBEET[†] Untreated				16.6 b	3.0 d	1669 d
CONV-TILL/CORN/CORN/SBEET				17.5 a	21.9 ab	6728 a
OUTLOOK	21 oz/a	POST1	B			
+ Roundup PowerMax	22 oz/a	POST1	B			
Roundup PowerMax	22 oz/a	POST2	C			
+ Ammonium Sulfate	0.8 gal/a					
CONV-TILL/CORN/CORN/SBEET				16.9 ab	24.4 a	7045 a
OUTLOOK	10.5 oz/a	POST1	B			
+ Roundup PowerMax	21.3 oz/a	POST1	B			
OUTLOOK	10.5 oz/a	POST2	C			
+ Roundup PowerMax	21.3 oz/a	POST2	C			
CONV-TILL/CORN/CORN/SBEET				16.9 ab	21.9 ab	6363 ab
OUTLOOK	21 oz/a	POST1	B			
+ Roundup PowerMax	21.3 oz/a	POST1	B			
Nortron	5.0 oz/a	POST2	C			
+ Roundup PowerMax	21.3 oz/a	POST2	C			
Roundup PowerMax	21.3 oz/a	POST3	D			
CONV-TILL/CORN/CORN/SBEET				17.2 ab	24.5 a	7297 a
OUTLOOK	21 oz/a	POST1	B			
+ Roundup PowerMax	21.3 oz/a	POST1	B			
Roundup PowerMax	21.3 oz/a	POST2	C			
+ Dual Magnum	1.33 pt/a	POST2	C			
Nortron	6.0 oz/a	POST3	D			
+ Roundup PowerMax	21.3 oz/a	POST3	D			
REDUCED-TILL/CORN/CORN/SBEET Untreated				- -	0.5 d	-- -
CONV-TILL/CORN/CORN/SBEET				17.2 ab	16.4 c	4892 c
OUTLOOK	21 oz/a	POST1	B			
+ Roundup PowerMax	22 oz/a	POST1	B			
Roundup PowerMax	22 oz/a	POST2	C			
CONV-TILL/CORN/CORN/SBEET				17.6 a	16.4 c	5036 c
OUTLOOK	10.5 oz/a	POST1	B			
+ Roundup PowerMax	21.3 oz/a	POST1	B			
OUTLOOK	10.5 oz/a	POST2	C			
+ Roundup PowerMax	21.3 oz/a	POST2	C			
CONV-TILL/CORN/CORN/SBEET				17.1 ab	17.3 bc	5110 c
OUTLOOK	21 oz/a	POST1	B			
+ Roundup PowerMax	21.3 oz/a	POST1	B			
Nortron	5.0 oz/a	POST2	C			
+ Roundup PowerMax	21.3 oz/a	POST2	C			
Roundup PowerMax	21.3 oz/a	POST3	D			
CONV-TILL/CORN/CORN/SBEET				17.2 ab	18.5 bc	5534 bc
OUTLOOK	21 oz/a	POST1	B			
+ Roundup PowerMax	21.3 oz/a	POST1	B			
Roundup PowerMax	21.3 oz/a	POST2	C			
+ Dual Magnum	1.33 pt/a	POST2	C			
Nortron	6.0 oz/a	POST3	D			
+ Roundup PowerMax	21.3 oz/a	POST3	D			

[†]CONV-TILL = conventional tillage; RED-Till = Reduced tillage /corn/corn/sugar beet = corn(2007)/corn(2008)/sugarbeet(2009).
[‡] POST1 = post-emergence herbicides on June 18; POST2 = post-emergence herbicides on June 23, 2009, POST3 = applied July 2. All POST treatments with Roundup included ammonium sulfate at 2.5% V/V.
[††]Means within a column with the same letter are not significantly different (LSD, P = 0.05).

Table 7. Corn yield in response to tillage and herbicides at the Malheur Experiment Station, Ontario, OR, 2008-2009.

Treatment	Rate		Timing[‡]	Code	Corn yield[††]
					------ bu/acre-------
Conventional-Tillage /CORN/SBEET/CORN[†] Untreated					124.8 b
Conventional-Tillage /CORN/SBEET/CORN					236.4 a
Roundup PowerMax	21.3	oz/a	POST1	B	
+ Ammonium Sulfate	0.8	gal/a		B	
Roundup PowerMax	21.3	oz/a	POST2	C	
+ Ammonium Sulfate	0.8	gal/a		C	
Conventional-Tillage /CORN/SBEET/CORN					235.4 a
OUTLOOK	21	oz/a	PPI	A	
+ Roundup PowerMax	21.3	oz/a	POST	B	
+ Ammonium Sulfate	0.8	gal/a		B	
Conventional-Tillage /CORN/SBEET/CORN					236.2 a
Dual II Magnum	1.5	pt/a	PPI	A	
Roundup PowerMax	21.3	oz/a	POST1	B	
+ Ammonium Sulfate	0.8	gal/a		B	
+ Basagran	2.0	pt/a		B	
Roundup PowerMax	21.3	oz/a	POST2	C	
+ Ammonium Sulfate	0.8	gal/a		C	
Conventional-Tillage/CORN/SBEET/CORN					216.3 a
Dual II Magnum	1.5	pt/a	PPI	A	
Roundup PowerMax	21.3	oz/a	POST1	B	
+ Ammonium Sulfate	0.8	gal/a		B	
+ Basagran	2.0	pt/a		B	
Roundup PowerMax	21.3	oz/a	POST2	C	
+ Basagran	1.5	pt/a		C	
+ Ammonium Sulfate	0.8	gal/a		C	
Reduced tillage					
Reduce-Tillage /CORN/SBEET/CORN Untreated					103.7 b
Reduce-Tillage /CORN/SBEET/CORN					200.8 a
Roundup PowerMax	21.3	oz/a	POST1	B	
+ Ammonium Sulfate	0.8	gal/a		B	
Roundup PowerMax	21.3	oz/a	POST2	C	
+ Ammonium Sulfate	0.8	gal/a		C	
Reduce-Tillage /CORN/SBEET/CORN					209.5 a
OUTLOOK	21	oz/a	PPI	A	
Roundup PowerMax	21.3	oz/a	POST	B	
+ Ammonium Sulfate	0.8	gal/a		B	
Reduce-Tillage /CORN/SBEET/CORN					218.7 a
Dual II Magnum	1.5	pt/a	PPI	A	
Roundup PowerMax	21.3	oz/a	POST1	B	
+ Ammonium Sulfate	0.8	gal/a		B	
+ Basagran	2.0	pt/a		B	
Roundup PowerMax	21.3	oz/a	POST2	C	
+ Ammonium Sulfate	0.8	gal/a		C	
Reduce-Tillage/CORN/SBEET/CORN					230.1 a
Dual II Magnum	1.5	pt/a	PPI	A	
Roundup PowerMax	21.3	oz/a	POST1	B	
+ Ammonium Sulfate	0.8	gal/a		B	
+ Basagran	2.0	pt/a		B	
Roundup PowerMax	21.3	oz/a	POST2	C	
+ Basagran	1.5	pt/a		C	

[†]Conventional-Tillage; Reduced-Tillage /corn/sbeet/corn = corn (2007)/ sugar beet (2008)/corn (2009).
[‡] PPI = Pre-plant incorporated; POST1 = post-emergence herbicides on June 18; POST2 = herbicides applied on June 24, 2009.
[††]Means within a column with the same letter are not significantly different (LSD, P = 0.05).

Table 8. Pinto bean yield in response to tillage and herbicides at the Malheur Experiment Station, Ontario, OR, 2008-2009.

Treatment	Rate		Timing[‡]	Code	Pinto bean yield[††]
					-------- T/A --------
Conventional-Tillage /CORN/CORN(Late)/PBEAN[†] Untreated					0.5 bc
Conventional-Tillage/CORN/CORN(Late)/PBEAN					1.0 ab
OUTLOOK	21	oz/a	PPI	A	
Raptor	4	oz/a	POST	B	
+ Basagran	12	fl oz/a		B	
Ammonium Sulfate	0.4	gal/a		B	
Conventional-Tillage /CORN/CORN(Late)/PBEAN					1.1 ab
OUTLOOK	14	fl oz/a	PPI	A	
OUTLOOK	7	fl oz/a	POST1	B	
+ Basagran	12	fl oz/a		B	
+ Ammonium Sulfate	3.2	pt/a		B	
Basagran	1.5	pt/a	POST2	C	
+ Ammonium Sulfate	0.4	gal/a		C	
Conventional-Tillage /CORN/CORN(Late)/PBEAN					0.9 ab
Dual II Magnum	1.33	pt/a	PPI	A	
+ Basagran	1.0	pt/a	POST1	B	
Raptor	4	oz/a		B	
+ Ammonium Sulfate	3.2	pt/a		B	
Basagran	1.0	pt/a	POST2	C	
+ Ammonium Sulfate	3.2	pt/a		C	
Conventional-Tillage/CORN/CORN(Late)/PBEAN					1.3 a
Dual II Magnum	1.33	pt/a	PPI	A	
+ Treflan EC	1.5	pt/a	PPI	A	
Basagran	1	pt/a	POST1	B	
+ OUTLOOK	18	oz/a		B	
+ Ammonium Sulfate	0.4	gal/a		B	
Basagran	2.0	pt/a	POST2	C	
+ Crop Oil Concentrate	2.0	pt/a		C	
Reduced tillage					
Reduced-Tillage/CORN/CORN(Late)/PBEAN Untreated					0.2 c
R-T/CORN/CORN(Late)/PBEAN					0.9 ab
OUTLOOK	21	oz/a	PPI	A	
Raptor	4	oz/a	POST	B	
+ Basagran	12	fl oz/a		B	
+ Ammonium Sulfate	0.4	gal/a		B	
Reduced-Tillage /CORN/CORN(Late)/PBEAN					0.7 abc
OUTLOOK	14	fl oz/a	PPI	A	
OUTLOOK	7	fl oz/a	POST1	B	
+ Basagran	12	fl oz/a		B	
+ Ammonium Sulfate	3.2	pt/a		B	
Basagran	1.5	pt/a	POST2	C	
+ Ammonium Sulfate	0.4	gal/a		C	
Reduced-Tillage /CORN/CORN(Late)/PBEAN					0.8 abc
Dual Magnum	1.33	pt/a	PPI	A	
Basagran	1.0	pt/a	POST1	B	
+ Raptor	4	oz/a		B	
+ Ammonium Sulfate	3.2	pt/a		B	
Basagran	1.0	pt/a	POST2	C	
+ Ammonium Sulfate	3.2	pt/a		C	
Reduced-Tillage /CORN/CORN(Late)/PBEAN					0.7 abc
Dual II Magnum	1.33	pt/a	PPI	A	
+ Treflan EC	1.5	pt/a	PPI	A	
Basagran	1	pt/a	POST1	B	
+ OUTLOOK	18	oz/a		B	
+ Ammonium Sulfate	0.4	gal/a		B	
Basagran	2.0	pt/a	POST2	C	
+ Crop Oil Concentrate	2.0	pt/a		C	

[†]Conventional-Tillage; Reduced-Tillage /corn/corn(late)/Pbean = corn (2007)/ corn (planted late) (2008)/pinto beans (2009).
[‡] PPI = Pre-plant incorporated applied May 13; POST1= post-emergence herbicides on June 19; POST2 = herbicides on July 2, 2009.
[††]Means within a column with the same letter are not significantly different (LSD, P = 0.05).