ONION HAS NO RESPONSE TO GLYPHOSATE APPLIED TO ROUNDUP®-RESISTANT CORN

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Introduction

Glyphosate is a nonselective herbicide used before emergence in sensitive crops and to control annual and perennial weeds in glyphosate-resistant crops. Glyphosate resistant (GR) corn and sugar beet form an important component of crop rotations in the Treasure Valley of eastern Oregon and southwestern Idaho. Glyphosate is the predominant herbicide used to control weeds in GR crops and it is applied multiple times throughout the season. The adoption of GR crops has simplified weed control and increased crop rotation options for growers.

The major herbicidal action of glyphosate is based on the inhibition of an enzyme that results in reduced biosynthesis of aromatic amino acids and alterations in protein metabolism. Research reports indicated that up to 80% of the glyphosate absorbed after foliar applications is translocated into shoot apex and plant root tips (Feng et al. 2003). Even at low foliar application rates, the root tips accumulate glyphosate at very high concentrations. It has been reported that only a single foliar application of glyphosate at a rate of 0.46 lb ae/acre (Roundup PowerMax® at 13 fl oz/acre) was enough to cause an injurious accumulation of glyphosate in the root tips, and this concentration could be much higher when glyphosate is applied at greater rates or repeatedly (McWhorter et al. 1980).

Recent research reports have suggested that accumulation of glyphosate in shoot apex or root tips at high amounts may induce impairments in cellular utilization of cationic mineral nutrients by reducing the free activity of these nutrients by chelation (Bernards et al. 2005). Kremer et al. (2005) observed that glyphosate may be released into the soil through GR root exudates and stimulate growth of selected rhizosphere fungi, possibly by providing a selective carbon and nitrogen source. There are, however, limited data on the effects of glyphosate on the mineral nutritional status of successive crop plants grown in rotation with GR crops that have been treated with multiple applications of glyphosate. The objective of this study was to evaluate the response of direct-seeded onion grown following 2 years of foliar applications of glyphosate to GR corn to determine whether glyphosate was interfering with onion nutrient uptake and onion yield.

Materials and Methods

A multi-year field study was conducted at the Malheur Experiment Station, Ontario, Oregon from 2012 to 2014. Glyphosate-resistant corn was planted in 2012 and 2013 in a field with a predominant Owyhee silt loam soil. The soil had 2.1% organic matter, 7.3 pH, and 20 meq/100 g of soil in 2012 and 2013. The soil properties in 2014 when the area was planted to onion are

presented in Table 1. Following wheat harvest in 2011, the field was moldboard plowed, disked, and beds formed on 22-inch spacing. Corn was planted in 2012 and 2013 following recommended local production practices. Individual plot size was 15 ft wide (8 beds) by 50 ft long. The integrity of the study area was maintained by using physical markers on each plot corner. To avoid dragging the soil across adjacent plots, all tillage operations were done along the bed length.

The corn herbicide treatments in 2012 and 2013 were:

	Glyphosate rate lb ae/acre	Other herbicides and adjuvants[a]	Rate	Application timing
1	0	Dual II Magnum®	1.54 pt/acre	Preemergence
		Laudis®	3.00 fl oz/acre	Postemergence
		Atrazine	4.00 fl oz/acre	
		Ammonium sulfate	1% v/v	
		MSO	1% v/v	
2	0.77	Dual II Magnum	1.54 pt/acre	Preemergence
	0.77	Ammonium sulfate	1% v/v	Early postemergence
	0.77	Ammonium sulfate	1% v/v	Postemergence
3	1.13	Dual II Magnum	1.54 pt/acre	Preemergence
	1.13	Ammonium sulfate	1% v/v	Early postemergence
	1.13	Ammonium sulfate		Postemergence

[a] Dual II Magnum = *S*-metolachlor at 1.47 lb ai/acre; Laudis = tembotrione 0.082 lb ai/acre, Atrazine = atrazine 0.125 lb ai/acre.

Herbicide treatments were applied using a tractor-mounted tank and spray boom equipped with 8002 EVS nozzles and a carrier volume of 20 gal/acre. Treatment 1 served as the control. The study followed a randomized complete block design with 12 replications.

Following the corn harvest in 2013, the stubble was flailed on October 17, 2013 and the field was rototilled twice. According to soil tests, the study area was fertilized with nitrogen (N) at 40 lb/acre, phosphorus (P) at 100 lb/acre, potassium (K) at 65 lb/acre, and 80 lb/acre of elemental sulfur (S) on October 18, 2013 and plowed. On October 31, 2013, the area was groundhogged without using a levelling bar to avoid dragging soil across plots. Later the field was fumigated with Telone® C-17 (1,3 dichloropropene 81.2% plus chloropicrin 16.5%) at 18 gal/acre and simultaneously bedded on a 22-inch row spacing.

The beds were harrowed, flattened, and seed of the onion variety 'Vaquero' was planted on March 20, 2014. Seed was planted in double rows spaced 3 inches apart and 4-inch seed spacing within each row on the 22-inch beds. 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 beds on March 21 and the soil surface was rolled.

The entire study area was sprayed with pendimethalin at 0.95 lb ai/acre (Prowl® H_2O at 32 fl oz/acre) on April 4, 2014. On April 7, plots for treatments 2 and 3 were sprayed with glyphosate at 0.77 lb ae/acre (Roundup PowerMax at 22 fl oz/acre), and treatment 1 was sprayed with Gramoxone® at 1.5 pt/acre plus 1% v/v to control all emerged weeds before onion emergence. The entire study area was sprayed with sethoxydim at 0.28 lb ai/acre (Poast® at 1.5 pt/acre) plus a crop oil concentrate at 2 pt/acre on May 19 to control grassy weeds. On May 20, the study area

was sprayed with Outlook® at 21 fl oz/acre (dimethenamid-p at 0.95 lb ai/acre). A tank mixture of oxyfluorfen at 0.25 lb ai/acre (GoalTender® at 8 oz/acre) plus bromoxynil at 0.125 lb ai/acre (Buctril® 8 oz/acre) was applied on May 21 to control broadleaf weeds. Onion emergence started on April 10. The number of onion plants was determined on May 8 by counting all plants in the two center beds of each plot. All other activities followed the standard local onion production practices. Postemergence treatments were applied on May 8 and May 29 when onion plants were at the 2-leaf and 4-leaf stage, respectively. The complete list of herbicide treatments and rates used on corn in 2012 and 2013 is presented in Tables 5-7. The onions were hand-weeded on June 17, 2014 and every 2 weeks as needed to keep the study free of weeds.

The first furrow irrigation was on April 14 and lasted 24 hours to supply about 4 inches of water (including runoff). All subsequent irrigations (17 times from May 29 to August 27, 2014) lasted the same duration and delivered the same amount of water.

On May 16 and July 3, 2014, 10 plants chosen randomly from each plot were measured from the ground to the tip of the longest fully extended leaf to determine the average plant height. The 10 plants were carefully dug and used to determine the root and above-ground biomass. The roots were carefully washed and cut off from the aboveground parts, dried in the greenhouse for 48 hours, and weighed to determine dry weight.

To control thrips, onions were sprayed with a tank mix of Movento® at 5 oz/acre (spirotetramat at 0.078 lb ai/acre) plus Radiant® at 8 oz/acre (spinetoram at 1 oz ai/acre) and Pierce (crop oil concentrate) at 16 oz/100 gal on May 29 and again on June 3, 2014. Onions were sprayed again to control thrips on June 12 and 17 using Agri-Mek® at 3.5 oz/acre plus non-ionic surfactant (NIS) at 10 oz/100 gal of water. Later sprays to control thrips were conducted aerially as follows: Agri-Mek at 3.5 oz/acre plus NIS at 10 oz/100 gal of water on June 30, Lannate® at 3 pt/acre (methomyl at 0.9 lb ai/acre) on July 6 and 13, and Radiant® at 10 oz/acre (spinetoram at 1.25 oz ai/acre) on July 22 and 27, 2014.

A soil probe was used to draw soil from the middle rows of each plot at 12-inch depth on May 30 and July 3, 2013 to determine soil nutrient content. A composite sample composed of 20 soil samples from plots belonging to a common treatment was analyzed to determine the soil nutrient content. Soil samples were analyzed at the Western Laboratories, Parma, Idaho following standard soil analysis procedures. Soil test results were used to formulate and apply fertilizer to onion for the yield desired. Onion plant root tissue were also sampled and analyzed on May 30, and July 3, 2014. Based on the soil test, the onions were sidedressed with fertilizer on June 3 to supply 164 lb/acre of N, 3 lb/acre of P, and 103 lb/acre of S.

Plant tops were flailed and onion bulbs were lifted on September 3 and 5, 2014, respectively. Bulbs were hand-harvested from the two center beds on September 10 and graded on September 16, 2013. Bulbs were graded for yield and quality based on USDA standards. Onion bulbs were graded according to diameter: small (<2¼ inches), medium (2¼-3 inches), jumbo (3-4 inches), colossal (4-4¼ inches), and supercolossal (>4¼ inches). U.S. No.1 and marketable yield were composed of medium, jumbo, colossal, and supercolossal grades. Data were subjected to analysis of variance and the treatment means were compared using protected LSD at 0.05% level of confidence.

Results and Discussion

Onion emergence was observed on April 10, 2014. The soil pH averaged 7.1 to 7.3 across herbicide treatments (Table 1). Percent soil organic matter was 2.2 to 2.5 across treatments and samplings.

Nutrient sufficiency ranges in Table 2 were used as a general guide to decide whether or not application of certain nutrients will result in yield increase. The categorization of soil solution (extractable) nutrient amount for phosphorus, potassium, calcium, magnesium, zinc, copper, and manganese for the soil test conducted on May 30, 2014 is presented in Table 2 for the three herbicide treatments. Subsequent soil solution test results for the soil drawn on July 3, 2014 are presented in Table 3. The test results for soil nutrient supply and plant needs per day were similar across herbicide treatments. These results suggested adequate availability of nutrients in the soil solution to satisfy onion crop needs during the season.

Onion root tissue sample tests for different nutrients on May 30 and July 3, 2014 were similar across the three herbicide treatments (Table 4). Nutrient values for manganese and iron were much higher than the sufficiency range at both sampling dates.

Onion plant stand on May 5, 2014 was similar across herbicide treatments and ranged from 126,143 to 128,527 plants/acre (Table 5). Similarly, no difference in the average plant height was observed on May 16 and July 3, 2014. The root and aboveground plant biomass was also similar across the herbicide treatments.

There were no differences among treatments for the small, medium, jumbo, colossal, and supercolossal onion yields (Table 6). The small onion yield ranged from 8 to 12 cwt/acre, 61 to 87 cwt/acre for medium, 737 to 772 cwt/acre for jumbo, 49 to 72 cwt/acre for colossal, and 0 to 3 cwt/acre for supercolossal. The marketable yield and total yields ranged from 873 to 903 and 885 to 911 cwt/acre, respectively. The number of bulbs for the different onion grades was also similar across herbicide treatments (Table 7).

These results indicate no adverse effects to onions planted following 2 years of glyphosate application to corn. We were not surprised by these results because the soil was fertilized annually based on soil analysis to supply the nutrients (both macro and micro) for the desired level of yield. Growers practicing standard soil analysis to determine the nutrient and the amount needed for the crop are not likely to experience nutrient deficiencies from glyphosate applications as suggested in some online publications.

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Table 1. Soil properties of the field planted to corn and sprayed with glyphosate 2 years (2012 and 2013) preceding onion at the Malheur Experiment Station, Oregon State University, Ontario, OR in 2014.

Soil properties	Glyphosate (kg ae/acre)		
	0.00	0.77	1.13
	May 30, 2014		
% organic matter	2.2	2.2	2.2
pH	7.3	7.1	7.1
Cation exchange capacity[a]	14.0	17.0	17.0
	July 3, 2014		
% organic matter	2.5	2.2	2.4
pH	7.2	7.2	7.2
Cation exchange capacity	23.0	22.0	21.0

[a] meq/100 g soil

Table 2. Nutrient sufficiency levels and soil test results in May for the corn/corn/onion study at the Malheur Experiment Station, Oregon State University, Ontario, OR, 2014.

		Extractable nutrient (soil solution) test on results on May 30, 2014								
		No glyphosate			Glyphosate 0.77 lb ae/acre			Glyphosate 1.13 lb ae/acre		
	Nutrient		Soil supply			Soil supply			Soil supply	
Nutrient	sufficiency range	Extractable	Result	Plant needs	Extractable	Result	Plant needs	Extractable	Result	Plant needs
	ppm	ppm	----- lb/day -----		ppm	----- lb/day -----		ppm	----- lb/day -----	
Phosphorus	(Olsen test)									
low	<10									
medium	10-25	37	2.1	2	28	3.7	2	38	3.1	2
high	25-50									
Potassium										
low	<150									
medium	150-250	413	31	10	447	28	10	430	27	10
high	250-800									
Calcium	1,800+	2,695	21	8	2,441	13	8	2,546	13	8
Magnesium										
low	<60									
medium	60-300	527	18	2	570	13	2	584	13	2
high	>300									
		ppm	oz	oz/day	ppm	oz	oz/day	ppm	oz	oz/day
Zinc	1-3	4.3	7	3	2.6	5.0	3	2.7	5.0	3
Copper	0.8-2.5	1.6	2	2	1.6	2.0	2	1.6	2.0	2
Manganese	6-30	9	5	3	11	11.3	3	7	10.2	3

Table 3. Nutrient sufficiency levels and soil test results in July for the corn/corn/onion study at the Malheur Experiment Station, Oregon State University, Ontario, OR, 2014.

		Extractable nutrient (soil solution) test on results on July 3, 2014								
		No glyphosate			Glyphosate 0.77 lb ae/acre			Glyphosate 1.13 lb ae/acre		
			Soil supply			Soil supply			Soil supply	
Nutrient	Nutrient sufficiency range	Extractable	Result	Plant needs	Extractable	Result	Plant needs	Extractable	Result	Plant needs
	ppm	ppm	------ lb/day ------		ppm	------ lb/day ------		ppm	------ lb/day ------	
Phosphorus	(Olsen test)									
low	<10									
medium	10-25	38	2.7	2	36	2.7	2	36	2.6	2
high	25-50									
Potassium										
low	<150									
medium	150-250	136	61	8	104	63	8	102	61	8
high	250-800									
Calcium	1,800+	2,037	24	2	1,829	24	2	1,906	23	2
Magnesium										
low	<60									
medium	60-300	450	14	1	430	14	1	442	14	1
high	>300									
		ppm	oz	oz/day	ppm	oz	oz/day	ppm	oz	oz/day
Zinc	1-3	2.2	3	2	2.4	3	2	2.6	3	2
Copper	0.8-2.5	16	6	1	1.1	2	1	13	3	1
Manganese	6-30	9	4.4	2	8	4.4	2	7	4.7	2

Table 4. Onion root tissue nutrient test on June 3 and July 3 for the corn/corn/onion study at the Malheur Experiment Station, Oregon State University, Ontario, OR in 2014.

		Tissue sampled May 30, 2014			Tissue sampled July 3, 2014		
	Nutrient sufficiency range	No glyphosate	Glyphosate 0.77 lb ae/acre	Glyphosate 1.13 lb ae/acre	No glyphosate	Glyphosate 0.77 lb ae/acre	Glyphosate 1.13 lb ae/acre
Nutrient		In-season root tissue test results					
Nitrate (ppm)	8,326 (4,237)*	146	134	530	4,984	2,462	1,502
Phosphorus (%)	0.32 – 0.70	0.55	0.57	0.52	0.62	0.70	0.70
Potassium (%)	2.70 – 6.00	3.15	3.11	3.04	4.58	4.79	4.96
Sulfur (%)	0.24 – 0.85	0.70	0.70	0.67	1.14	1.29	1.27
Calcium (%)	0.40 – 1.20	0.65	0.67	0.66	0.92	1.34	0.91
Magnesium (%)	0.30 – 0.60	0.31	0.31	0.31	0.45	0.48	0.46
Zinc (ppm)	25 – 50	25	69	26	27	29	30
Manganese (ppm)	35 – 100	64	75	76	1,016	1,161	1,144
Copper (ppm)	6 – 20	9	12	12	86	95	99
Iron (ppm)	60 – 250	1,691	1,938	1,830	3,070	3,089	4,010
Boron (ppm)	19 – 60	20	23	23	3	8	6

*sufficiency value for the July 3, 2014 soil test

Table 5. Onion plant stand on May 5, 2014, average plant height (inches) on May 16, root and above ground weight (grams) on May 18, plant height (inches) on July 3, and root and above ground weight (grams) on July 3, 2014 in a field planted to corn and sprayed with glyphosate for 2 years before planting onion at the Malheur Experiment Station, Oregon State University, Ontario, OR 2014.

					Onion attributes[a]						
						Sampled on May 16, 2014			Sampled on July 3, 2014		
	Corn herbicide treatments in 2012 and 2013	Rate	Unit	Timing[b]	Stand	Plant height	Root weight	Bulb and top weight	Plant height	Root weight	Bulb and top weight
					no./acre	inches	grams	grams	inches	grams	grams
1	Hand-weeded				126,143 a	9.8 a	0.69 a	1.76 a	28.9 a	8.5 a	91.7 a
	Dual II Magnum	1.47	lb ai/a	A							
	Laudis	0.082	lb ai/a	B							
	Atrazine	0.125	lb ai/a	B							
	AMM-sulfate	1.5	lb ai/a	B							
	MSO	1.57	lb ai/a	B							
2	Dual II Magnum	1.47	lb ai/a	A	128,527 a	9.7 a	0.68 a	1.69 a	28.8 a	8.9 a	88.6 a
	glyphosate	0.77	lb ae/a	B							
	AMM-sulfate	2.5	% v/v	B							
	glyphosate	0.77	lb ae/a	C							
	AMM-sulfate	2.5	% v/v	C							
3	glyphosate	1.13	lb ae/a	B	126,776 a	9.5 a	0.67 a	1.68 a	29.1 a	8.9 a	91.8 a
	AMM-sulfate	2.5	% v/v	B							
	glyphosate	1.13	lb ae/a	C							
	AMM-sulfate	2.5	% v/v	C							
	glyphosate	1.13	lb ae/a	D							
	AMM-sulfate	2.5	% v/v	D							
LSD (*P* = 0.05)					5,536	0.7	0.16	0.27	1.2	1.4	11.7

[a] Means within a column followed by same letter do not significantly differ (*P* = 0.05, LSD).
[b] Herbicides used on corn in 2012 and 2013. Timing: A = pre-emergence; B = early postemergence, postemergence.

Table 6. Onion yield in response to glyphosate applied to corn during the preceding 2 years at the Malheur Experiment Station, Oregon State University, Ontario, OR, 2014.

	Corn herbicide treatments in 2012 and 2013	Rate	Unit	Timing[b]	Onion yield[a] <2¼ in Small	2¼-3 in Medium	3-4 in Jumbo	4-4¼ in Colossal	>4¼ in Super-colossal	Marketable U.S. No. 1	Total yield
					cwt/acre						
1	Hand-weeded				11.8 a	86.6 a	737.4 a	49.1 a	0.0 a	873.1 a	884.9 a
	Dual II Magnum	1.47	lb ai/a	A							
	Laudis	0.082	lb ai/a	B							
	Atrazine	0.125	lb ai/a	B							
	AMM-sulfate	1.5	lb ai/a	B							
	MSO	1.57	lb ai/a	B							
2	Dual II Magnum	1.47	lb ai/a	A	7.7 a	66.1 b	772.2 a	61.3 a	3.4 a	903.0 a	910.7 a
	glyphosate	0.77	lb ae/a	B							
	AMM-sulfate	2.5	% v/v	B							
	glyphosate	0.77	lb ae/a	C							
	AMM-sulfate	2.5	% v/v	C							
3	glyphosate	1.13	lb ae/a	B	10.5 a	60.7 b	758.4 a	72.4 a	2.8 a	894.3 a	904.8 a
	AMM-sulfate	2.5	% v/v	B							
	glyphosate	1.13	lb ae/a	C							
	AMM-sulfate	2.5	% v/v	C							
	glyphosate	1.13	lb ae/a	D							
	AMM-sulfate	2.5	% v/v	D							
LSD (*P* = 0.05)					NS	19.6	NS	NS	NS	NS	NS

[a] Means within a column followed by same letter do not significantly differ (*P* = 0.05, LSD).
[b] Herbicides used on corn in 2012 and 2013. Timing: A = preemergence; B = early postemergence, postemergence.

Table 7. Number of onion bulbs in response to glyphosate applied to corn during the preceding 2 years at the Malheur Experiment Station, Oregon State University, Ontario, OR, 2014.

					Onion bulbs[a]						
	Corn herbicide treatments in 2012 and 2013	Rate	Unit	Timing[b]	<2¼ in Small	2¼-3 in Medium	3-4 in Jumbo	4-4¼ in Colossal	>4¼ in Super-colossal	Marketable U.S. No. 1	Total yield
					number/acre						
1	Hand-weeded				6,231 a	22,354 a	95,053 a	3,956 a	0 a	121,363 a	127,594 a
	Dual II Magnum	1.47	lb ai/a	A							
	Laudis	0.082	lb ai/a	B							
	Atrazine	0.125	lb ai/a	B							
	AMM-sulfate	1.5	lb ai/a	B							
	MSO	1.57	lb ai/a	B							
2	Dual II Magnum	1.47	lb ai/a	A	3,956 a	16,815 b	99,800 a	4,946 a	198 a	121,758 a	125,715 a
	glyphosate	0.77	lb ae/a	B							
	AMM-sulfate	2.5	% v/v	B							
	glyphosate	0.77	lb ae/a	C							
	AMM-sulfate	2.5	% v/v	C							
3	glyphosate	1.13	lb ae/a	B	5,737 a	16,320 b	97,130 a	5,737 a	198 a	119,384 a	125,121 a
	AMM-sulfate	2.5	% v/v	B							
	glyphosate	1.13	lb ae/a	C							
	AMM-sulfate	2.5	% v/v	C							
	glyphosate	1.13	lb ae/a	D							
	AMM-sulfate	2.5	% v/v	D							
LSD (*P* = 0.05)					NS	5,020	NS	NS	NS	NS	NS

[a] Means within a column followed by same letter do not significantly differ (*P* = 0.05, LSD).
[b] Herbicides used on corn in 2012 and 2013. Timing: A = pre-emergence; B = early postemergence, postemergence.