

Supplementary materials

Impact of reducing synthetic chemical inputs on pest and disease management in commercial onion production systems

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Figure S1. Nutrient levels from muck soil sampled in onion fields in July 2019 (A), May 2020 (B), July 2020 (C), May 2021 (D) and June 2021 (E) in New York (USA). Results are illustrated as the percent difference in nutrients from sample transects where no fertilizer was applied to those receiving either a half or full rate of N-P-K fertilizer applied. Error bars represent standard error. No differences were detected between half and full rates of fertilizer for any nutrient in this study (2019-2021).

Table S1. Locations, cultivars, planting and harvest dates for all onion fields sampled in New York (USA) in 2019, 2020, and 2021. All field locations differed each year.

Year	Location					
2019	Orleans Co.	GPS coordinates	Cultivar	Days to Maturity	Planting Date	Harvest Date
	Field 1	43°09'15.3"N 78°06'42.2"W	Bradley	118	16-Apr	9-Sep
	Field 2	43°08'20.7"N 78°06'40.6"W	Montclair	112	15-Apr	4-Sep
	Field 3	43°07'53.1"N 78°06'53.4"W	Bradley	118	13-Apr	4-Sep
	Field 4	43°07'58.6"N 78°07'05.5"W	Crockett	118	17-Apr	9-Sep
2020	Orleans Co.					
	Field 1	43°08'20.9"N 78°06'37.4"W	Montclair	112	20-Apr	8-Sep
	Field 2	43°09'16.7"N 78°06'37.8"W	Safrane	106	29-Apr	8-Sep
	Field 3	43°08'03.9"N 78°06'45.3"W	Bradley	118	21-Apr	8-Sep
	Field 4	43°07'58.9"N 78°07'05.7"W	Crockett	118	2-Apr	8-Sep
	Field 5	43°08'42.6"N 78°06'33.3"W	Hamilton	120	7-Apr	8-Sep
	Wayne Co.					
	Field 6	43°13'24.6"N 77°04'21.3"W	Safrane	106	8-May	1-Sep
	Field 7	43°10'08.0"N 77°03'52.9"W	Fortress	110	29-Apr	1-Sep
	Field 8	43°10'05.8"N 77°03'57.7"W	Safrane	106	29-Apr	1-Sep
2021	Orleans Co.					
	Field 1	43°07'58.9"N 78°07'05.7"W	Crockett	118	6-Apr	1-Sep
	Field 2	43°08'41.9"N 78°06'35.0"W	Hamilton	120	8-Apr	1-Sep
	Field 3	43°08'21.8"N 78°06'42.2"W	Montclair	112	7-Apr	1-Sep
	Field 4	43°09'16.8"N 78°06'35.2"W	Safrane	106	10-Apr	1-Sep
	Field 5	43°08'37.5"N 78°07'44.0"W	Bradley	118	31-Mar	1-Sep
	Wayne Co.					
	Field 6	43°08'19.7"N 77°04'31.4"W	Safrane	106	26-Apr	27-Aug
	Field 7	43°09'32.3"N 77°03'40.9"W	Stanley	110	23-Apr	19-Aug
	Field 8	43°09'32.3"N 77°03'41.6"W	Fortress	110	24-Apr	19-Aug

Table S2. Amount of synthetic N-P-K fertilizer applied in each onion field at planting each year, as well as the rates recommended by the 2019 Cornell Integrated Crop and Pest Management Guidelines for Commercial Vegetable Production for growing dry bulb onions on muck soils in New York (USA). All field locations differed each year.

Year	Location	Nitrogen (kg ha ⁻¹)		Phosphorus (kg ha ⁻¹)		Potassium (kg ha ⁻¹)	
		Half	Full	Half	Full	Half	Full
2019	Field 1	70	140	78	156	81	162
	Field 2	70	140	78	156	81	162
	Field 3	62	125	56	112	85	170
	Field 4	50	100	84	168	112	224
2020	Field 1	67	134	63	126	63	126
	Field 2	67	134	63	126	63	126
	Field 3	63	126	57	113	85	169
	Field 4	50	101	84	168	112	224
	Field 5	50	101	84	168	112	224
	Field 6	51	102	38	76	110	220
	Field 7	50	100	38	76	139	277
	Field 8	50	100	38	76	139	277
2021	Field 1	67	134	63	126	63	126
	Field 2	67	134	63	126	63	126
	Field 3	63	126	57	113	85	169
	Field 4	73	146	84	168	112	224
	Field 5	73	146	84	168	112	224
	Field 6	51	102	38	76	110	220
	Field 7	50	100	38	76	139	277
	Field 8	50	100	38	76	139	277

Recommended rates of N are 112 to 140 kg ha⁻¹; P are 56 to 168 kg ha⁻¹; K are 56 to 168 kg ha⁻¹.

Table S3. Example composition of typical fertilizer mix that onion growers order custom-blended based on soil test results.

Ingredient Name	Composition	Amount in Mixture (kg)
Copper	0-0-0-12Cu	22.7
Manganese Oxy-Sulfate	0-0-0-18.5S-32Mn	22.7
Ammonium Sulfate	12-0-0-24S	121.6
K-Mag	0-0-22-22S	127
Monoammonium Phosphate	11-52-0	244.9
Potassium Chloride	0-0-60	172.4
Urea	44-0-0	196
Final Mixture	15N-14P-14K-6.8S-0.3Cu-0.675Mn-0.15Zn	907.2

Table S4. Insecticides and rates applied in all onion fields in this study, including those made following an action threshold-based spray program and the additional sprays made in the weekly spray program in New York (USA) in 2019, 2020, and 2021.

Year	County	Location	Application Date	Action Threshold Treatment				Weekly Treatment			
				IRAC MOA	Active ingredient	Trade Name	Amt. Applied (g ha ⁻¹)	IRAC MOA	Active ingredient	Trade Name	Amt. Applied (g ha ⁻¹)
2019	Orleans	Field 1	10-Jul	23	Spirotetramat	Movento	87.6	23	Spirotetramat	Movento	87.6
			18-Jul	23	Spirotetramat	Movento	87.6	23	Spirotetramat	Movento	87.6
			25-Jul			---		6	Abamectin	Agri-Mek SC	21.4
			2-Aug	5	Spinetoram	Radiant SC	87.6	5	Spinetoram	Radiant SC	87.6
			8-Aug			---		5	Spinetoram	Radiant SC	70.0
			15-Aug	5	Spinetoram	Radiant SC	70.0	5	Spinetoram	Radiant SC	70.0
			23-Aug	28	Cyantraniliprole	Exirel	116.2	28	Cyantraniliprole	Exirel	116.2
			29-Aug	28	Cyantraniliprole	Exirel	116.2	28	Cyantraniliprole	Exirel	116.2
		Field 2	10-Jul	23	Spirotetramat	Movento	87.6	23	Spirotetramat	Movento	87.6
			18-Jul	23	Spirotetramat	Movento	87.6	23	Spirotetramat	Movento	87.6
			25-Jul			---		6	Abamectin	Agri-Mek SC	21.4
			1-Aug	5	Spinetoram	Radiant SC	87.6	5	Spinetoram	Radiant SC	87.6
			8-Aug			---		5	Spinetoram	Radiant SC	70.0
			15-Aug	5	Spinetoram	Radiant SC	70.0	5	Spinetoram	Radiant SC	70.0
			23-Aug			---		28	Cyantraniliprole	Exirel	116.2
		Field 3	4-Jul	23	Spirotetramat	Movento	87.6	23	Spirotetramat	Movento	87.6
			15-Jul	23	Spirotetramat	Movento	87.6	23	Spirotetramat	Movento	87.6
			23-Jul			---		6	Abamectin	Agri-Mek SC	21.4
			30-Jul			---		6	Abamectin	Agri-Mek SC	21.4
			8-Aug	28	Cyantraniliprole	Exirel	98.1	28	Cyantraniliprole	Exirel	98.1

			16-Aug	5	Spinetoram	Radiant SC	70.0	5	Spinetoram	Radiant SC	70.0
			23-Aug	5	Spinetoram	Radiant SC	70.0	5	Spinetoram	Radiant SC	70.0
Field 4			3-Jul	23	Spirotetramat	Movento	87.6	23	Spirotetramat	Movento	87.6
			11-Jul	23	Spirotetramat	Movento	87.6	23	Spirotetramat	Movento	87.6
			18-Jul			---		6	Abamectin	Agri-Mek SC	21.4
			25-Jul			---		6	Abamectin	Agri-Mek SC	21.4
			30-Jul			---		28	Cyantraniliprole	Exirel	98.1
			7-Aug	28	Cyantraniliprole	Exirel	98.1	28	Cyantraniliprole	Exirel	98.1
			16-Aug			---		5	Spinetoram	Radiant SC	70.0
			23-Aug			---		5	Spinetoram	Radiant SC	70.0
2020	Orleans	Field 1	9-Jul	23	Spirotetramat	Movento	87.6	23	Spirotetramat	Movento	87.6
			16-Jul	23	Spirotetramat	Movento	87.6	23	Spirotetramat	Movento	87.6
			23-Jul	6 + 28	Abamectin + Cyantraniliprole	Minecto Pro	14.7 + 69.3	6 + 28	Abamectin + Cyantraniliprole	Minecto Pro	14.7 + 69.3
			31-Jul			---		1A + 3A	Methomyl + Lambda- cyhalothrin	Lannate LV + Warrior II w/ zeon tech.	1008.6 + 34.6
			6-Aug			---		28	Cyantraniliprole	Exirel	98.1
			13-Aug	5	Spinetoram	Radiant	87.6	5	Spinetoram	Radiant SC	87.6
			20-Aug	6 + 28	Abamectin + Cyantraniliprole	Minecto Pro	14.7 + 69.3	6 + 28	Abamectin + Cyantraniliprole	Minecto Pro	14.7 + 69.3
		Field 2	9-Jul	23	Spirotetramat	Movento	87.6	23	Spirotetramat	Movento	87.6
			16-Jul	23	Spirotetramat	Movento	87.6	23	Spirotetramat	Movento	87.6
			24-Jul			---		1A + 3A	Methomyl + Lambda- cyhalothrin	Lannate LV + Warrior II w/ zeon tech.	1008.6 + 34.6

	30-Jul	6 + 28	Abamectin + Cyantraniliprole	Minecto Pro	14.7 + 69.3	6 + 28	Abamectin + Cyantraniliprole	Minecto Pro	14.7 + 69.3
	6-Aug	5	Spinetoram	Radiant SC	87.6	5	Spinetoram	Radiant SC	87.6
	13-Aug	5	Spinetoram	Radiant SC	87.6	5	Spinetoram	Radiant SC	87.6
	20-Aug	6 + 28	Abamectin + Cyantraniliprole	Minecto Pro	14.7 + 69.3	6 + 28	Abamectin + Cyantraniliprole	Minecto Pro	14.7 + 69.3
Field 3	10-Jul	23	Spirotetramat	Movento	87.6	23	Spirotetramat	Movento	87.6
	20-Jul	23	Spirotetramat	Movento	87.6	23	Spirotetramat	Movento	87.6
	31-Jul	---				6	Abamectin	Agri-Mek SC	21.4
	6-Aug	5	Spinetoram	Radiant SC	70.0	5	Spinetoram	Radiant SC	70.0
	13-Aug	5	Spinetoram	Radiant SC	70.0	5	Spinetoram	Radiant SC	70.0
Field 4	6-Jul	23	Spirotetramat	Movento	87.6	23	Spirotetramat	Movento	87.6
	13-Jul	23	Spirotetramat	Movento	87.6	23	Spirotetramat	Movento	87.6
	20-Jul	6 + 3A	Abamectin + Lambda- cyhalothrin	Agri-Mek SC + Lamcap II	21.4 + 35.6	6 + 3A	Abamectin + Lambda- cyhalothrin	Agri-Mek SC + Lamcap II	21.4 + 35.6
	27-Jul	5	Spinetoram	Radiant SC	87.6	5	Spinetoram	Radiant SC	87.6
	5-Aug	5	Spinetoram	Radiant SC	87.6	5	Spinetoram	Radiant SC	87.6
	12-Aug	6 + 28	Abamectin + Cyantraniliprole	Minecto Pro	14.7 + 69.3	6 + 28	Abamectin + Cyantraniliprole	Minecto Pro	14.7 + 69.3
	20-Aug			---		1A + 3A	Methomyl + Lambda- cyhalothrin	Lannate LV + Warrior II w/ zeon tech.	1008.6 + 34.6
	24-Aug	5	Spinetoram	Radiant SC	70.0	5	Spinetoram	Radiant SC	70.0
Field 5	6-Jul	23	Spirotetramat	Movento	87.6	23	Spirotetramat	Movento	87.6

13-Jul	23	Spirotetramat	Movento	87.6	23	Spirotetramat	Movento	87.6
20-Jul	6 + 3A	Abamectin + Lambda- cyhalothrin	Agri-Mek SC + Lamcap II	21.4 + 35.6	6 + 3A	Abamectin + Lambda- cyhalothrin	Agri-Mek SC + Lamcap II	21.4 + 35.6
27-Jul	5	Spinetoram	Radiant	87.6	5	Spinetoram	Radiant SC	87.6
5-Aug	5	Spinetoram	Radiant	87.6	5	Spinetoram	Radiant SC	87.6
12-Aug	6 + 28	Abamectin + Cyantraniliprole	Minecto Pro	14.7 + 69.3	6 + 28	Abamectin + Cyantraniliprole	Minecto Pro	14.7 + 69.3
20-Aug			---		1A + 3A	Methomyl + Lambda- cyhalothrin	Lannate LV + Warrior II w/zeon tech.	1008.6 + 34.6
24-Aug	5	Spinetoram	Radiant SC	70.0	5	Spinetoram	Radiant SC	70.0

Wayne	Field 6	26-Jun	23	Spirotetramat	Movento	87.6	23	Spirotetramat	Movento	87.6
		4-Jul	23	Spirotetramat	Movento	87.6	23	Spirotetramat	Movento	87.6
		9-Jul			---		1A + 3A	Methomyl + Lambda- cyhalothrin	Lannate LV + Warrior II w/ zeon tech.	1008.6 + 34.6
		25-Jul	6	Abamectin	Reaper	21.0	6	Abamectin	Reaper	21.0
		31-Jul	6 + 28	Abamectin + Cyantraniliprole	Minecto Pro	14.7 + 69.3	6 + 28	Abamectin + Cyantraniliprole	Minecto Pro	14.7 + 69.3
		7-Aug	5	Spinetoram	Radiant SC	70.0	5	Spinetoram	Radiant SC	70.0
		14-Aug	5	Spinetoram	Radiant SC	70.0	5	Spinetoram	Radiant SC	70.0
		22-Aug	5	Spinetoram	Radiant SC	70.0	5	Spinetoram	Radiant SC	70.0
	Field 7	26-Jun	23	Spirotetramat	Movento	87.6	23	Spirotetramat	Movento	87.6
		3-Jul	23	Spirotetramat	Movento	87.6	23	Spirotetramat	Movento	87.6

							1A + 3A	Methomyl + Lambda- cyhalothrin	Lannate LV + Warrior II w/ zeon tech.	1008.6 + 34.6
							1A + 3A	Methomyl + Lambda- cyhalothrin	Lannate LV + Warrior II w/ zeon tech.	1008.6 + 34.6
		24-Jul	6 + 28	Abamectin + Cyantraniliprole	Minecto Pro	14.7 + 69.3	6 + 28	Abamectin + Cyantraniliprole	Minecto Pro	14.7 + 69.3
		31-Jul			---		6	Abamectin	Agri-Mek SC	21.4
		5-Aug	5	Spinetoram	Radiant SC	87.6	5	Spinetoram	Radiant SC	87.6
		12-Aug	5	Spinetoram	Radiant SC	87.6	5	Spinetoram	Radiant SC	87.6
Field 8		26-Jun	23	Spirotetramat	Movento	87.6	23	Spirotetramat	Movento	87.6
		3-Jul	23	Spirotetramat	Movento	87.6	23	Spirotetramat	Movento	87.6
		9-Jul			---		1A + 3A	Methomyl + Lambda- cyhalothrin	Lannate LV + Warrior II w/ zeon tech.	1008.6 + 34.6
		17-Jul			---		1A + 3A	Methomyl + Lambda- cyhalothrin	Lannate LV + Warrior II w/ zeon tech.	1008.6 + 34.6
		24-Jul	6 + 28	Abamectin + Cyantraniliprole	Minecto Pro	14.7 + 69.3	6 + 28	Abamectin + Cyantraniliprole	Minecto Pro	14.7 + 69.3
		31-Jul			---		6	Abamectin	Agri-Mek SC	21.4
		5-Aug	5	Spinetoram	Radiant SC	87.6	5	Spinetoram	Radiant SC	87.6
		12-Aug	5	Spinetoram	Radiant SC	87.6	5	Spinetoram	Radiant SC	87.6
2021	Orleans	Field 1	9-Jun	23	Spirotetramat	Movento	23	Spirotetramat	Movento	87.6
			16-Jun	23	Spirotetramat	Movento	23	Spirotetramat	Movento	87.6

	23-Jun		---			1A + 3A	Methomyl + Lambda- cyhalothrin	Lannate LV + Warrior II w/ zeon tech.	1008.6 + 34.6
	30-Jun	6 + 28	Abamectin + Cyantraniliprole	Minecto Pro	14.7 + 69.3	6 + 28	Abamectin + Cyantraniliprole	Minecto Pro	14.7 + 69.3
	8-Jul	6 + 28	Abamectin + Cyantraniliprole	Minecto Pro	14.7 + 69.3	6 + 28	Abamectin + Cyantraniliprole	Minecto Pro	14.7 + 69.3
	14-Jul	5	Spinetoram	Radiant SC	70.0	5	Spinetoram	Radiant SC	70.0
	21-Jul		---			6 + 3A	Abamectin + Lambda- cyhalothrin	Agri-Mek SC + Warrior II w/zeon tech.	21.4 + 35.0
	28-Jul	5	Spinetoram	Radiant SC	87.6	5	Spinetoram	Radiant SC	87.6
	4-Aug	5	Spinetoram	Radiant SC	87.6	5	Spinetoram	Radiant SC	87.6
	11-Aug	28	Cyantraniliprole	Exirel	145.3	28	Cyantraniliprole	Exirel	145.3
	20-Aug	28	Cyantraniliprole	Exirel	98.1	28	Cyantraniliprole	Exirel	98.1
Field 2	21-Jun	23	Spirotetramat	Movento	87.6	23	Spirotetramat	Movento	87.6
	28-Jun	23	Spirotetramat	Movento	87.6	23	Spirotetramat	Movento	87.6
	7-Jul		---			1A + 3A	Methomyl + Lambda- cyhalothrin	Lannate LV + Warrior II w/ zeon tech.	1008.6 + 34.6
	15-Jul	6 + 28	Abamectin + Cyantraniliprole	Minecto Pro	14.7 + 69.3	6 + 28	Abamectin + Cyantraniliprole	Minecto Pro	14.7 + 69.3
	21-Jul		---			1A + 3A	Methomyl + Lambda- cyhalothrin	Lannate LV + Warrior II w/ zeon tech.	1008.6 + 34.6
	28-Jul	6 + 28	Abamectin + Cyantraniliprole	Minecto Pro	14.7 + 69.3	6 + 28	Abamectin + Cyantraniliprole	Minecto Pro	14.7 + 69.3
	4-Aug	5	Spinetoram	Radiant SC	87.6	5	Spinetoram	Radiant SC	87.6

	11-Aug	5	Spinetoram	Radiant SC	87.6	5	Spinetoram	Radiant SC	87.6
	20-Aug	28	Cyantraniliprole	Exirel	98.1	28	Cyantraniliprole	Exirel	98.1
Field 3	10-Jun	23	Spirotetramat	Movento	87.6	23	Spirotetramat	Movento	87.6
	17-Jun	23	Spirotetramat	Movento	87.6	23	Spirotetramat	Movento	87.6
	23-Jun		---			1A + 3A	Methomyl + Lambda- cyhalothrin	Lannate LV + Warrior II w/ zeon tech.	1008.6 + 34.6
							Methomyl + Lambda- cyhalothrin	Lannate LV + Warrior II w/ zeon tech.	
	30-Jun					1A + 3A			
	10-Jul	6 + 28	Abamectin + Cyantraniliprole	Minecto Pro	14.7 + 69.3	6 + 28	Abamectin + Cyantraniliprole	Minecto Pro	14.7 + 69.3
		6 + 28	Abamectin + Cyantraniliprole	Minecto Pro	14.7 + 69.3	6 + 28	Abamectin + Cyantraniliprole	Minecto Pro	14.7 + 69.3
	15-Jul								
	21-Jul		---			6 + 3A	Abamectin + Lambda- cyhalothrin	Agri-Mek SC + Warrior II w/zeon tech.	21.4 + 35.0
	29-Jul	5	Spinetoram	Radiant SC	87.6	5	Spinetoram	Radiant SC	87.6
	6-Aug	5	Spinetoram	Radiant SC	87.6	5	Spinetoram	Radiant SC	87.6
	12-Aug	28	Cyantraniliprole	Exirel	116.3	28	Cyantraniliprole	Exirel	116.3
	20-Aug	28	Cyantraniliprole	Exirel	145.3	28	Cyantraniliprole	Exirel	145.3
Field 4	10-Jun	23	Spirotetramat	Movento	87.6	23	Spirotetramat	Movento	87.6
	17-Jun	23	Spirotetramat	Movento	87.6	23	Spirotetramat	Movento	87.6
	23-Jun		---			1A + 3A	Methomyl + Lambda- cyhalothrin	Lannate LV + Warrior II w/ zeon tech.	1008.6 + 34.6

			---			1A + 3A	Methomyl + Lambda- cyhalothrin	Lannate LV + Warrior II w/ zeon tech.	1008.6 + 34.6
	30-Jun								
	10-Jul	6 + 28	Abamectin + Cyantraniliprole	Minecto Pro	14.7 + 69.3	6 + 28	Abamectin + Cyantraniliprole	Minecto Pro	14.7 + 69.3
	15-Jul	6 + 28	Abamectin + Cyantraniliprole	Minecto Pro	14.7 + 69.3	6 + 28	Abamectin + Cyantraniliprole	Minecto Pro	14.7 + 69.3
						6 + 3A	Abamectin + Lambda- cyhalothrin	Agri-Mek SC + Warrior II w/zeon tech.	21.4 + 35.0
	21-Jul								
	29-Jul	5	Spinetoram	Radiant SC	87.6	5	Spinetoram	Radiant SC	87.6
	5-Aug	5	Spinetoram	Radiant SC	87.6	5	Spinetoram	Radiant SC	87.6
	12-Aug	28	Cyantraniliprole	Exirel	116.3	28	Cyantraniliprole	Exirel	116.3
	20-Aug	28	Cyantraniliprole	Exirel	145.3	28	Cyantraniliprole	Exirel	145.3
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Field 5	10-Jun	23	Spirotetramat	Movento	87.6	23	Spirotetramat	Movento	87.6
	17-Jun	23	Spirotetramat	Movento	87.6	23	Spirotetramat	Movento	87.6
						1A + 3A	Methomyl + Lambda- cyhalothrin	Lannate LV + Warrior II w/ zeon tech.	1008.6 + 34.6
	23-Jun								
	1-Jul	6	Abamectin	Agri-Mek SC	21.4	6	Abamectin	Agri-Mek SC	21.4
	9-Jul	6	Abamectin	Agri-Mek SC	21.4	6	Abamectin	Agri-Mek SC	21.4
	15-Jul	28	Cyantraniliprole	Exirel	116.3	28	Cyantraniliprole	Exirel	116.3
	21-Jul					28	Cyantraniliprole	Exirel	116.3
	30-Jul	5	Spinetoram	Radiant SC	87.6	5	Spinetoram	Radiant SC	87.6
	7-Aug	5	Spinetoram	Radiant SC	87.6	5	Spinetoram	Radiant SC	87.6
	14-Aug	5	Spinetoram	Radiant SC	87.6	5	Spinetoram	Radiant SC	87.6

Wayne	Field 6	25-Jun	23	Spirotetramat	Movento	87.6	23	Spirotetramat	Movento	87.6
		2-Jul	23	Spirotetramat	Movento	87.6	23	Spirotetramat	Movento	87.6
		7-Jul		---			1A + 3A	Methomyl + Lambda- cyhalothrin	Lannate LV + Warrior II w/ zeon tech.	1008.6 + 34.6
				---			1A + 3A	Methomyl + Lambda- cyhalothrin	Lannate LV + Warrior II w/ zeon tech.	1008.6 + 34.6
				---			6 + 3A	Abamectin + Lambda- cyhalothrin	Agri-Mek SC + Warrior II w/zeon tech.	21.4 + 35.0
		22-Jul	6 + 28	Abamectin + Cyantraniliprole	Minecto Pro	14.7 + 69.3	6 + 28	Abamectin + Cyantraniliprole	Minecto Pro	14.7 + 69.3
		29-Jul								
		4-Aug					5	Spinetoram	Radiant SC	70.0
	Field 7	28-Jun	23	Spirotetramat	Movento	87.6	23	Spirotetramat	Movento	87.6
		6-Jul	23	Spirotetramat	Movento	87.6	23	Spirotetramat	Movento	87.6
		14-Jul					1A + 3A	Methomyl + Lambda- cyhalothrin	Lannate LV + Warrior II w/ zeon tech.	1008.6 + 34.6
		21-Jul					1A + 3A	Methomyl + Lambda- cyhalothrin	Lannate LV + Warrior II w/ zeon tech.	1008.6 + 34.6
		28-Jul	6 + 28	Abamectin + Cyantraniliprole	Minecto Pro	14.7 + 69.3	6 + 28	Abamectin + Cyantraniliprole	Minecto Pro	14.7 + 69.3
		7-Aug	6 + 28	Abamectin + Cyantraniliprole	Minecto Pro	14.7 + 69.3	6 + 28	Abamectin + Cyantraniliprole	Minecto Pro	14.7 + 69.3
		14-Aug		---			28	Cyantraniliprole	Exirel	98.1

Field 8	28-Jun	23	Spirotetramat	Movento	87.6	23	Spirotetramat	Movento	87.6
	6-Jul	23	Spirotetramat	Movento	87.6	23	Spirotetramat	Movento	87.6
	14-Jul			---		1A + 3A	Methomyl + Lambda- cyhalothrin	Lannate LV + Warrior II w/ zeon tech.	1008.6 + 34.6
	21-Jul			---		1A + 3A	Methomyl + Lambda- cyhalothrin	Lannate LV + Warrior II w/ zeon tech.	1008.6 + 34.6
	28-Jul	6 + 28	Abamectin + Cyantraniliprole	Minecto Pro	14.7 + 69.3	6 + 28	Abamectin + Cyantraniliprole	Minecto Pro	14.7 + 69.3
	7-Aug	6 + 28	Abamectin + Cyantraniliprole	Minecto Pro	14.7 + 69.3	6 + 28	Abamectin + Cyantraniliprole	Minecto Pro	14.7 + 69.3
	14-Aug			---		28	Cyantraniliprole	Exirel	98.1

If two products were applied concurrently as a tank mixture or bottled pre-mixture, both are listed and separated by a + symbol for each box.

Table S5. Summary ANOVA table of soil nutrient levels in the portions of all onion fields that received half and full application rates of N-P-K fertilizer compared with zero fertilizer applied in New York (USA) in 2019, 2020, and 2021.

Year	Sample Date	Nutrient	df	F
2019				
	July			
		Nitrogen	2, 7	0.75
		Phosphorus	2, 7	3.8 †
		Potassium	2, 7	1.18
2020				
	May			
		Nitrogen	2, 16	12.33***
		Phosphorus	2, 16	1.61
		Potassium	2, 16	9.23 **
	July			
		Nitrogen	2, 16	8.46**
		Phosphorus	2, 16	0.65
		Potassium	2, 16	13.03 ***
2021				
	May			
		Nitrogen	2, 16	7.41 **
		Phosphorus	2, 16	1.83
		Potassium	2, 16	4.86 *
	July			
		Nitrogen	2, 16	5.00 *
		Phosphorus	2, 16	2.11
		Potassium	2, 16	20.39 ***

Asterisks indicated significant differences at the 0.05 level (*), 0.01 level (**), or 0.001 level (***). Values that approached significance (0.05-0.1) are denoted with (†). Random effect structure included the effects of field and sampling transect nested within field.

Table S6. Mean temperature and mean total precipitation in the two general regions where our study was conducted in New York (USA) in 2019, 2020, and 2021.

County	Month	Temperature (C°)			Precipitation (mm)		
		2019	2020	2021	2019	2020	2021
Orleans	April	6.8	5.4	7.9	82.3	95.3	110.7
	May	12.5	12.4	13.3	113.5	51.8	35.6
	June	18.1	19.8	20.9	94.7	54.1	70.1
	July	22.3	23.4	20.1	52.3	134.9	216.9
	August	19.7	20.7	22.3	87.9	46.5	62.2
Wayne	April	---	5.7	8.4	---	44.5	65.5
	May	---	12.6	13.8	---	45.7	50.5
	June	---	19.7	21.1	---	15.2	86.1
	July	---	25.0	20.4	---	24.1	186.9
	August	---	21.7	22.7	---	88.9	116.8

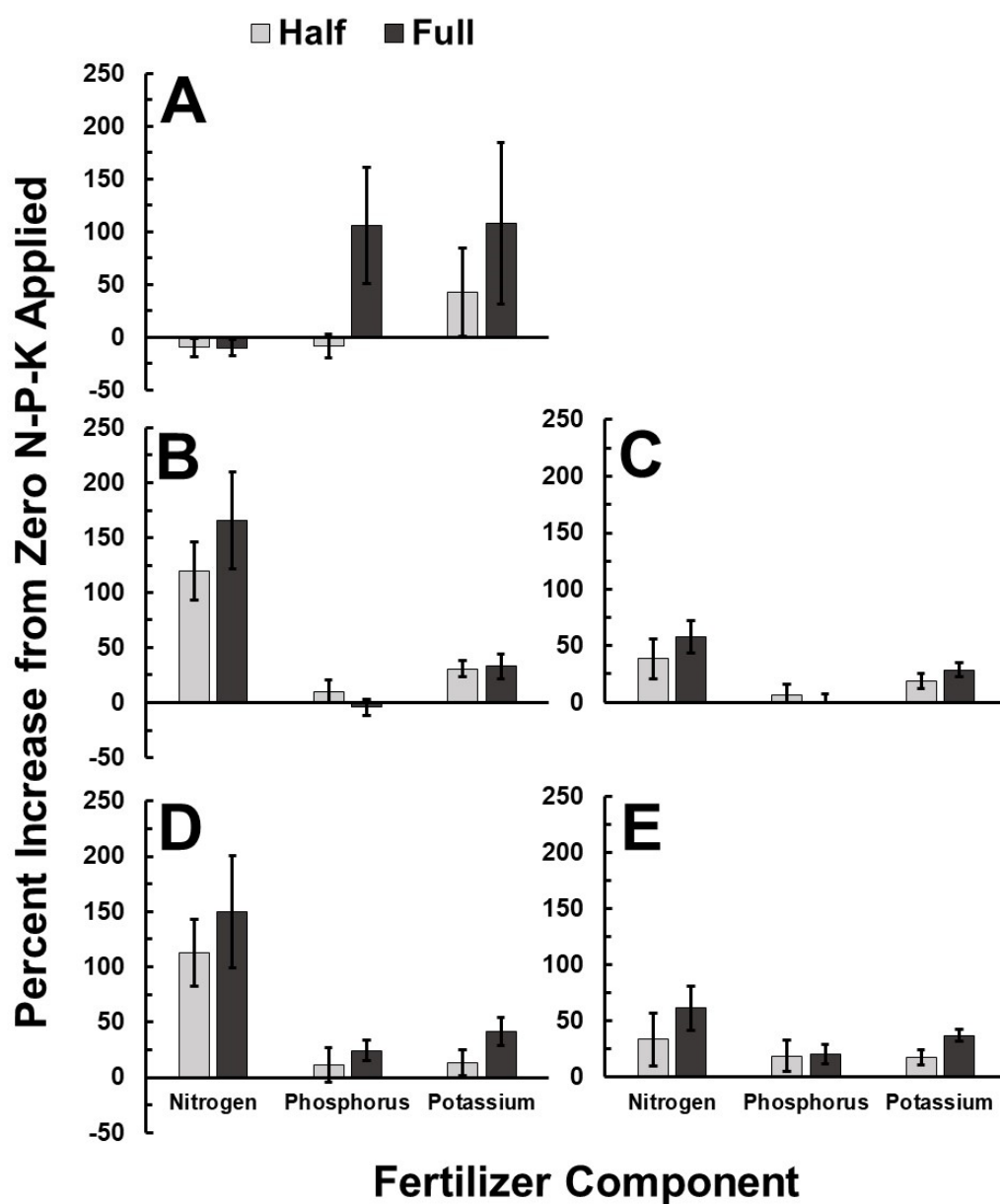


Figure S1. Nutrient levels from muck soil sampled in onion fields in July 2019 (A), May 2020 (B), July 2020 (C), May 2021 (D) and June 2021 (E) in New York (USA). Results are illustrated as the percent difference in nutrients from sample transects where no fertilizer was applied to those receiving either a half or full rate of N-P-K fertilizer applied. Error bars represent standard error. No significant differences were detected between half and full rates of fertilizer for any nutrient in this study (2019-2021).