ONION RESPONSE TO IN-SEASON NUTRIENT SUPPLEMENTATION STRATEGIES AND AT-PLANTING PHOSPHORUS APPLICATION IN 2015

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Introduction

Germinating onion seed and new onion seedlings have difficulty obtaining adequate phosphorus for ideal early growth. Low soil temperatures in Oregon and Idaho can reduce soil phosphorus availability early in the growing season. Phosphorus application at planting could enhance early onion growth and yield. Applying plant nutrients in small amounts during the season is feasible with drip irrigation. The increased use of drip irrigation in onion production has lead to the need for evaluating plant and soil analytical methods to guide in-season nutrient supplementation. Two methods that can be used to determine the need for in-season nutrient supplementation are root tissue analysis and soil solution analysis. This trial tested nutrient supplementation based on tissue and soil solution tests and phosphorus application at planting using two onion varieties.

Materials and Methods

Onions were grown in 2015 on an Owyhee silt loam. The field had been planted to wheat in 2014. In the fall of 2014, the wheat stubble was shredded and the field was irrigated. The field was then disked, moldboard plowed, and groundhogged. A soil analysis taken in the fall of 2014 showed that the top foot of soil had a pH of 7.1, 3.1-5.5% lime, 1.66% organic matter, 101% base saturation, 20 ppm nitrate, 7 ppm ammonium, 34 ppm phosphorus (P), 252 ppm potassium (K), 3709 ppm calcium (Ca), 293 ppm magnesium (Mg), 146 ppm sodium (Na), 4.8 ppm zinc (Zn), 1.2 ppm copper (Cu), 7 ppm manganese (Mn), 9 ppm iron (Fe), and 0.8 ppm boron (B). Based on the soil analysis, 75 lb/acre of P, 200 lb/acre of K, 23 lb/acre of sulfur (S), 20 lb/acre of Mg, 7 lb/acre of Mn, and 1 lb of B/acre were broadcast before plowing. After plowing, the field was fumigated with K-Pam® at 15 gal/acre and bedded at 22 inches.

Seed was planted on March 13 in double rows spaced 3 inches apart at 9 seeds/ft of single row. Each double row was planted on beds spaced 22 inches apart. Planting was done with customized John Deere Flexi Planter units equipped with disc openers. Immediately after planting, the onions received a narrow band of Lorsban® 15G at 3.7 oz/1000 ft of row (0.82 lb ai/acre) over the planted rows, and the soil surface was rolled. Onion emergence started on March 30.

The field had drip tape laid at 4-inch depth between pairs of onion beds during planting. The drip tape had emitters spaced 12 inches apart and emitter flow rate of 0.22 gal/min/100 ft (Toro

Aqua-Traxx, Toro Co., El Cajon, CA). The distance between the tape and the center of each double row of onions was 11 inches.

The experimental design was a split-plot randomized complete block with six replicates. There were five main treatments with variable fertilization amounts, timings, and methods of application:

1. **Check**: nutrients were added in the fall by soil analysis only. Only nitrogen (N) was added during the season by historical estimate.

2. **Root tissue analysis**: nutrients were added in the fall by soil analysis, and then nutrients were added through the season based on root tissue analysis.

3. **Soil solution analysis**: nutrients were added in the fall by soil analysis, and then nutrients were added through the season based on soil solution analysis.

4. **Soil solution analysis minus N**: nutrients were added in the fall by soil analysis, and then nutrients were added through the season based on soil solution analysis. Nitrogen was added based on root tissue analysis.

5. **Phosphorus sidedress**: P, Avail®, and humic acid were sidedressed at planting, nutrients had been added in the fall by soil analysis, and then nutrients were added through the season based on root tissue analysis.

Two yellow onion varieties ('Vaquero', Nunhems, Parma, ID and 'Avalon', Crookham, Caldwell, ID) were planted as split plots within each main plot. Main plots were 4 double rows wide by 54 ft long. Variety split plots were 27 ft long.

On March 20, P, Avail, and humic acid were applied to all plots of treatment 5. The nutrients were sidedressed between the seed row and the drip tape at 3-inch depth. The P was applied as phosphoric acid (NUE 0-30-0, Bio-Gro, Mabton, WA) at 26 lb P/acre. Humic acid and Avail were mixed with the phosphoric acid. Humic acid was applied at 6 gal/acre (CHB Premium 6, Bio-Gro, 5% humic acid) and Avail (Simplot, Caldwell, ID) at 0.5% of the final volume.

On May 12, 4-ft alleys were cut between split plots. On May 13, onions were thinned by hand to 120,000 plants/acre (4.75 inches between plants in each single row).

Starting on May 29 and every week thereafter, four plants with their bulbs and roots were sampled from the nonharvest rows of each Vaquero split plot of each treatment and the bulbs and roots washed in deionized water. One composite sample from each treatment consisting of the roots from all plots in each treatment was sent to Western Laboratories, Inc. (Parma, ID) for nutrient analysis.

Every week starting on May 29, soil samples from each plot of each treatment were collected. Each sample consisted of a composite of 7 soil cores to 9-inch depth from the center of nonharvested onion double rows in each plot. One composite sample from each treatment consisting of the soil from all plots in each treatment was sent to Western Laboratories, Inc. for soil solution analysis. The soil solution analysis is a proprietary analysis developed by Western Laboratories, Inc. that uses a weak acid extraction of the soil nutrients to simulate the extraction capacity of plant roots. Soil solution analysis estimated the amount of each nutrient that the soil can supply to the crop per day (Table 12).

For treatments 2-5, nutrients were applied weekly based on root tissue and/or soil solution analysis (Table 11). Each treatment had a separate mainline that supplied water to the drip tape in all plots for that treatment. Nutrients were injected independently into the drip irrigation system of each treatment using an Ozawa Precision Metering Pump (Ozawa R and D, Ontario, OR).

Onions were irrigated automatically to maintain the soil water tension (SWT) in the onion root zone below 20 cb. Soil water tension was measured in each Vaquero split plot in each main plot of replicate 3 with four granular matrix sensors (GMS, Watermark Soil Moisture Sensors Model 200SS, Irrometer Co., Riverside, CA) installed at 8-inch depth in the center of the double row. Sensors had been calibrated to SWT (Shock et al. 1998). The GMS were connected to the datalogger via multiplexers (AM 410 multiplexer, Campbell Scientific, Logan, UT). The datalogger read the sensors and recorded the SWT every hour. The datalogger automatically made irrigation decisions every 12 hours as previously described (Shock et al. 2002). The irrigation decisions were based on the average SWT of all plots.

The irrigation durations were 8 hours, 19 min to supply 0.48 inches of water per irrigation as had been previously shown to optimize onion performance at Ontario in silt loam (Shock et al. 2005). The irrigations were controlled by the datalogger using a controller (SDM CD16AC controller, Campbell Scientific, Logan, UT) connected to a solenoid valve. The irrigation water was supplied from a well by a pump that maintained a continuous and constant water pressure of 35 psi. The pressure in the drip lines was maintained at 10 psi by pressure regulators in each plot. The automated irrigation system was started on May 1. Irrigations were terminated on August 24.

The onions were managed to minimize yield reductions from weeds, pests, diseases, water stress, and nutrient deficiencies. For weed control, the following herbicides were applied: on March 26, Roundup PowerMax® at 24 oz/acre was broadcast; on April 28, GoalTender® at 0.09 lb ai/acre (4 oz/acre), Buctril® at 0.25 lb ai/acre (16 oz/acre), and Poast® at 0.25 lb ai/acre (16 oz/acre) were broadcast; on May 4, Prowl® H_2O at 0.83 lb ai/acre (2 pt/acre) was broadcast.

For thrips control, the following insecticides were applied: M-Pede® at 36 oz/acre and Aza-Direct® at 2 pt/acre on May 14; Movento® at 5 oz/acre on May 23 by ground application; Movento at 5 oz/acre and Aza-Direct at 2 pt/acre on June 4 by ground application; Agri-Mek® at 3.5 oz/acre on June 12 and 18 by ground application; Radiant® at 10 oz/acre on June 25 by ground application and on July 4 by aerial application; Lannate® at 0.9 lb ai/acre on July 15 and 25 by aerial application; and Radiant at 10 oz/acre on August 8 by aerial application.

For disease control, Badge® fungicide at 0.28 lb ai/acre (1 pt/acre) was broadcast aerially on June 4.

All split plots were evaluated for maturity and for severity of symptoms of iris yellow spot virus (IYSV) on August 4. Onions were evaluated subjectively for maturity by visually rating the percentage of onions with the tops down and the percent dry leaves. The number of bolted onion plants was counted in each split plot. Onions in each split plot were given a subjective rating on a scale of 0 to 5 of increasing severity of IYSV symptoms. The rating was 0 if there were no symptoms, 1 if 1-25% of foliage was diseased, 2 if 26-50% of foliage was diseased, 3 if 51-75% of foliage was diseased, 4 if 76-99% of foliage was diseased, and 5 if 100% of foliage was diseased.

The onions were lifted on August 31 to field cure. Onions from the middle 2 rows in each split plot were topped by hand and bagged on September 7. The bags were put in storage on September 9. The storage shed was ventilated and the temperature was slowly decreased to maintain air temperature as close to 34°F as possible. Onions were graded out of storage on November 19.

During grading, bulbs were separated according to quality: bulbs without blemishes (No. 1s), split bulbs (No. 2s), and bulbs infected with neck rot (*Botrytis allii*) in the neck or side, plate rot (*Fusarium oxysporum*), or black mold (*Aspergillus niger*). The No. 1 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). Marketable bulbs were No. 1 supercolossal, colossal, jumbo, and medium bulbs. Bulb counts per 50 lb of supercolossal onions were determined for each plot of every variety by weighing and counting all supercolossal bulbs during grading.

Treatment differences were compared using analysis of variance, ANOVA. Means separation was determined using a protected Fisher's least significant difference test at the 5% probability level, LSD (0.05).

Results and Discussion

Soil water tension remained close to the target of 20 cb during the season (Fig. 1).

To begin with root nitrate levels were deficient and only went above the critical level starting July 20 for some treatments and starting July 24 for all treatments (Table 1). Soil solution N levels went above the critical level for all treatments starting June 12. Root P levels were below the critical level on May 29 and again starting July 31 for all treatments (Table 2). Soil solution P levels only went below the critical level on one sampling date for treatments 1 and 5. Root K levels went below the critical level starting on July 10 for all treatments (Table 3). Soil solution K levels went below the critical level on 2 of the 12 sampling dates for all treatments and on 4 sampling dates for some treatments.

Root Mn, S, Ca, Zn, and Cu levels were above the critical level for all treatments on all sampling dates (Tables 4 to 10). Soil solution Mn levels were below the critical level for most treatments during all sampling dates. Soil solution S, Zn, and Cu levels went below the critical level for some treatments on some dates. Soil solution Ca and Mg levels were above the critical level for all treatments during all sampling dates.

Nitrogen, P, and K applications to treatment 2, based on root tissue analysis, were substantially higher than N, P, and K applications, based on soil solution analysis to treatment 3. Phosphorus and K applications to treatments 3 and 4, based on soil solution analysis, were similar. Nitrogen applications to treatment 4, based on root tissue analysis were higher than N applications to treatment 3, based on soil solution analysis. Based on root tissue analysis, a total of 143 lbs of N/acre was applied to treatment 2, compared to a total of 63 lbs of N/acre applied to treatment 3, based on soil solution analysis.

Analysis of total available N in the soil samples taken for the soil solution tests showed that there were substantial amounts of available N in the top foot of soil all season (Table 13).

Effects of the fertilization treatments

There was no significant difference in yield or any onion yield category between the fertigation treatments for either variety (Table 14). There was no significant difference in IYSV symptom severity between the fertigation treatments for either variety.

Avalon had higher total, supercolossal, colossal, and jumbo yield than Vaquero. Avalon had higher storage decomposition than Vaquero.

Economic benefits of the fertilization treatments

Based on the fall soil analysis, yield responses to P and K application would not be expected. For fumigated soils with 5% lime content in the Treasure Valley, when soil P concentration is 25 ppm or higher, no response to P is expected (Sullivan et al. 2001). Also, when soil K concentration is 100 ppm or higher, no response to K is expected (Sullivan et al. 2001). The fall soil analysis showed 34 ppm P, 252 ppm K, and 3.1-5.5% free lime. Research at the Parma Research and Extension Center, Parma, Idaho showed that even in a soil with low P concentration (6.8-8.2 ppm P) and high lime content (11-12% lime), onion yield responded to added P in only 1 out of the 3 years (Brown 2001).

The lack of yield response to nutrient supplementation based on root tissue tests in this trial was consistent with the soil solution analyses, which showed that levels of all nutrients, except N and Mn, remained above critical levels all season. According to the soil solution analyses, N was deficient only until June 12. However, the root tissue analyses indicated N was deficient until July 20, resulting in an additional 80 lb N/acre applied to treatments based on root tissue testing.

The use of root tissue analyses in conjunction with soil solution analyses could be beneficial as indicated by the situation of Mn in this trial. The soil solution analysis indicated a Mn shortage in the soil during most of the season, but the root tissue test indicated a Mn level above the adequate range during most of the season, which negated the need for Mn supplementation.

The 2013 and 2014 fertigation trial results were consistent with the current trial (Shock et al. 2013a,b; 2014). In both 2013 and 2014, nutrient supplementation based on root tissue testing did not increase onion yields. As in 2015, there was also no benefit from P supplementation at planting in 2013 and 2014. The soil solution analyses showed that only Cu in 2013 and Mn in 2014 went below the critical level at some samplings. As in 2015, the root tissue analyses in 2013 and 2014 showed that both Cu and Mn were within or above the adequate range.

Conclusions

The 2013, 2014, and 2015 trials were conducted on fumigated Owyhee silt loam soils with adequate levels of P and K, and low free lime. Phosphorus supplementation at planting did not increase onion yield or grade in any year. Nutrient supplementation during the season based on root tissue analyses did not increase onion yield or grade in any year. Nutrient supplementation during the season based on soil solution analyses was only indicated for Cu in 2013 and Mn in 2014 and 2015, which did not increase onion yield or grade. The root tissue analyses showed that Cu in 2013, and Mn in 2014 and 2015 were within or above the adequate range. These results suggest that onion growers may be able to reduce nutrient applications through the combined use of root tissue and soil solution testing. The 2015 results also showed that N

supplementation can be substantially reduced based on soil solution testing without any loss of yield or grade.

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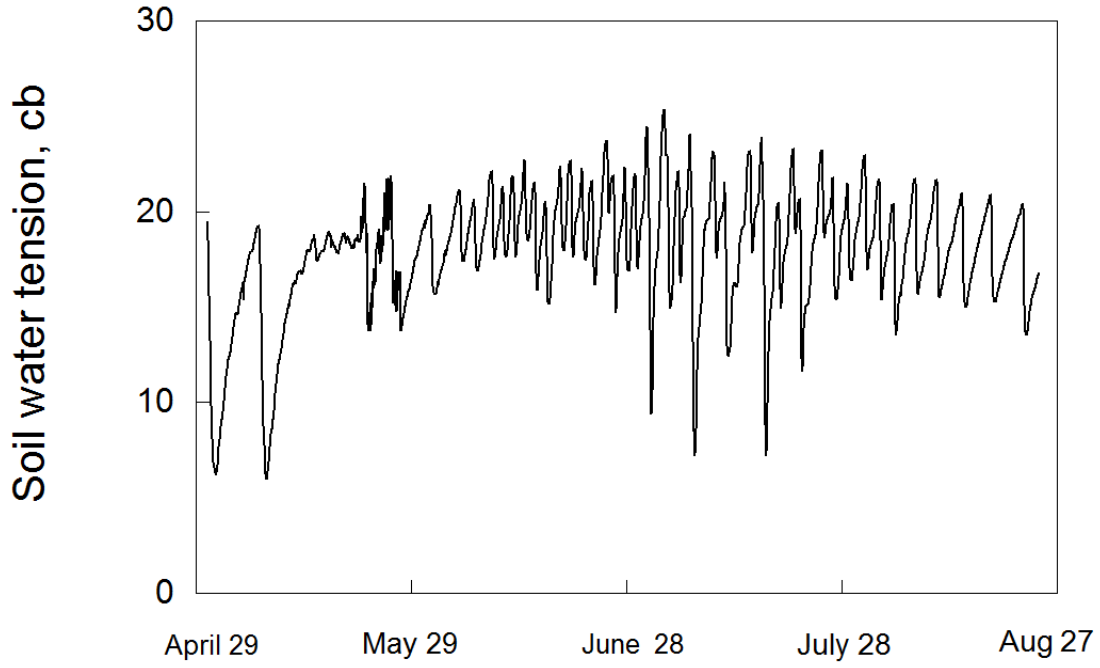

Figure 1. Soil water tension at 8-inch depth for onions irrigated at a soil water tension of 20 cb. Malheur Experiment Station, Oregon State University, Ontario, OR, 2015.

Table 1. Nitrate-N concentration (ppm) in onion root tissue for five fertigation treatments. Malheur Experiment Station, Oregon State University, Ontario, OR, 2015.

		Treatment				
Date	Critical level	1	2	3	4	5
29-May	8500	3118	3422	4791	3227	2661
8-Jun	7500	4296	3198	3224	3840	3203
12-Jun	6500	4398	4415	4451	4141	4115
19-Jun	5500	2532	2287	2636	3354	2336
26-Jun	4500	2410	2066	2068	2636	1985
6-Jul	4000	2079	1893	1723	2117	1545
10-Jul	3000	1638	2296	1299	2642	1959
20-Jul	2500	1990	3030	1174	3269	2407
24-Jul	1250	1689	3762	1177	3554	2963
31-Jul	500	1393	4254	1221	4006	2242
7-Aug	500	1557	3541	1014	3689	2523
17-Aug	500	1247	2880	934	2846	2516

Table 2. Phosphorus concentration (%) in onion root tissue for five fertigation treatments. Malheur Experiment Station, Oregon State University, Ontario, OR, 2015.

		Treatment				
Date	Sufficiency range	1	2	3	4	5
29-May	0.32 - 0.7	0.31	0.33	0.31	0.30	0.23
8-Jun	0.32 - 0.7	0.62	0.66	0.69	0.54	0.68
12-Jun	0.32 - 0.7	0.50	0.55	0.63	0.76	0.71
19-Jun	0.32 - 0.7	0.69	0.52	0.63	0.62	0.88
26-Jun	0.32 - 0.7	0.56	0.55	0.63	0.70	0.68
6-Jul	0.32 - 0.7	0.44	0.42	0.50	0.60	0.60
10-Jul	0.32 - 0.7	0.41	0.45	0.52	0.52	0.50
20-Jul	0.32 - 0.7	0.42	0.32	0.40	0.41	0.38
24-Jul	0.32 - 0.7	0.35	0.26	0.34	0.37	0.36
31-Jul	0.32 - 0.7	0.26	0.21	0.25	0.22	0.32
7-Aug	0.32 - 0.7	0.30	0.21	0.32	0.24	0.30
17-Aug	0.32 - 0.7	0.32	0.22	0.22	0.23	0.22

Table 3. Potassium concentration (%) in onion root tissue for five fertigation treatments. Malheur Experiment Station, Oregon State University, Ontario, OR, 2015.

		Treatment				
Date	Sufficiency range	1	2	3	4	5
29-May	2.7 - 6.0	3	3	3	3	3
8-Jun	2.7 - 6.0	5	5	6	6	5
12-Jun	2.7 - 6.0	5.26	2.82	3.30	3.09	3.10
19-Jun	2.7 - 6.0	3.67	3.53	3.34	3.60	3.90
26-Jun	2.7 - 6.0	2.83	3.11	3.02	3.95	3.20
6-Jul	2.7 - 6.0	2.78	2.59	2.82	3.05	2.50
10-Jul	2.7 - 6.0	2.02	1.87	2.10	2.62	2.13
20-Jul	2.7 - 6.0	2.29	1.49	2.31	2.31	2.22
24-Jul	2.7 - 6.0	2.45	1.18	2.20	2.03	2.30
31-Jul	2.7 - 6.0	1.87	0.87	1.96	1.83	1.51
7-Aug	2.7 - 6.0	1.59	1.07	1.61	1.64	1.11
17-Aug	2.7 - 6.0	1.50	0.97	1.21	1.41	0.96

Table 4. Sulfur concentration (%) in onion root tissue for five fertigation treatments. Malheur Experiment Station, Oregon State University, Ontario, OR, 2015.

		Treatment				
Date	Sufficiency range	1	2	3	4	5
29-May	0.24 - 0.85	0.87	1.05	1.03	1.02	1.15
8-Jun	0.24 - 0.85	0.48	0.52	0.54	0.40	0.50
12-Jun	0.24 - 0.85	0.58	0.90	0.29	0.29	0.26
19-Jun	0.24 - 0.85	0.30	0.40	0.30	0.40	0.20
26-Jun	0.24 - 0.85	0.44	0.62	0.46	0.84	0.54
6-Jul	0.24 - 0.85	0.50	0.68	0.52	0.95	0.50
10-Jul	0.24 - 0.85	0.62	0.79	0.65	0.81	0.44
20-Jul	0.24 - 0.85	0.79	1.02	0.77	0.99	0.50
24-Jul	0.24 - 0.85	0.94	1.15	1.00	1.03	0.65
31-Jul	0.24 - 0.85	1.04	0.85	0.94	0.84	0.42
7-Aug	0.24 - 0.85	1.01	0.53	1.09	0.86	0.56
17-Aug	0.24 - 0.85	1.05	0.68	0.81	0.85	0.65

Table 5. Calcium concentration (%) in onion root tissue for five fertigation treatments. Malheur Experiment Station, Oregon State University, Ontario, OR, 2015.

		Treatment				
Date	Sufficiency range	1	2	3	4	5
29-May	0.4 - 1.2	0.57	0.62	0.62	0.56	0.58
8-Jun	0.4 - 1.2	0.99	1.09	1.16	0.94	1.13
12-Jun	0.4 - 1.2	1.09	0.95	1.07	1.09	0.99
19-Jun	0.4 - 1.2	0.62	0.67	0.64	0.63	0.61
26-Jun	0.4 - 1.2	0.71	0.68	0.61	0.73	0.64
6-Jul	0.4 - 1.2	0.60	0.81	0.73	0.62	0.66
10-Jul	0.4 - 1.2	0.53	0.58	0.56	0.59	0.55
20-Jul	0.4 - 1.2	0.62	0.82	0.65	0.78	0.72
24-Jul	0.4 - 1.2	0.88	1.04	0.72	0.98	0.99
31-Jul	0.4 - 1.2	0.81	1.03	0.72	1.30	0.67
7-Aug	0.4 - 1.2	0.86	0.96	1.03	1.36	1.00
17-Aug	0.4 - 1.2	1.03	1.02	1.18	1.53	1.40

Table 6. Magnesium concentration (%) in onion root tissue for five fertigation treatments. Malheur Experiment Station, Oregon State University, Ontario, OR, 2015.

		Treatment				
Date	Sufficiency range	1	2	3	4	5
29-May	0.3 - 0.6	0.35	0.37	0.37	0.38	0.40
8-Jun	0.3 - 0.6	0.36	0.37	0.36	0.33	0.42
12-Jun	0.3 - 0.6	0.40	0.36	0.41	0.42	0.39
19-Jun	0.3 - 0.6	0.41	0.41	0.50	0.30	0.20
26-Jun	0.3 - 0.6	0.34	0.32	0.30	0.36	0.21
6-Jul	0.3 - 0.6	0.32	0.36	0.31	0.32	0.25
10-Jul	0.3 - 0.6	0.30	0.40	0.20	0.40	0.36
20-Jul	0.3 - 0.6	0.23	0.35	0.13	0.33	0.34
24-Jul	0.3 - 0.6	0.32	0.36	0.18	0.32	0.31
31-Jul	0.3 - 0.6	0.24	0.23	0.21	0.28	0.39
7-Aug	0.3 - 0.6	0.21	0.22	0.20	0.21	0.20
17-Aug	0.3 - 0.6	0.25	0.25	0.26	0.25	0.26

Table 7. Zinc concentration (%) in onion root tissue for five fertigation treatments. Malheur Experiment Station, Oregon State University, Ontario, OR, 2015.

		Treatment				
Date	Sufficiency range	1	2	3	4	5
29-May	25 - 50	42	39	47	46	43
8-Jun	25 - 50	40	41	46	37	51
12-Jun	25 - 50	37	38	40	65	45
19-Jun	25 - 50	53	56	47	48	50
26-Jun	25 - 50	54	46	46	64	51
6-Jul	25 - 50	44	41	50	52	50
10-Jul	25 - 50	52	44	49	43	40
20-Jul	25 - 50	52	58	58	48	48
24-Jul	25 - 50	38	38	48	36	35
31-Jul	25 - 50	32	27	28	36	44
7-Aug	25 - 50	39	25	35	37	37
17-Aug	25 - 50	47	31	48	42	42

Table 8. Manganese concentration (%) in onion root tissue for five fertigation treatments. Malheur Experiment Station, Oregon State University, Ontario, OR, 2015.

		Treatment				
Date	Sufficiency range	1	2	3	4	5
29-May	35 - 100	121	114	119	122	115
8-Jun	35 - 100	99	97	95	99	26
12-Jun	35 - 100	119	116	108	90	85
19-Jun	35 - 100	133	137	130	111	140
26-Jun	35 - 100	102	120	121	114	130
6-Jul	35 - 100	123	120	118	119	101
10-Jul	35 - 100	102	150	133	175	136
20-Jul	35 - 100	123	207	167	139	168
24-Jul	35 - 100	104	111	132	133	138
31-Jul	35 - 100	96	102	70	121	248
7-Aug	35 - 100	112	57	100	105	201
17-Aug	35 - 100	57	46	68	57	168

Table 9. Copper concentration (%) in onion root tissue for five fertigation treatments. Malheur Experiment Station, Oregon State University, Ontario, OR, 2015.

		Treatment				
Date	Sufficiency range	1	2	3	4	5
29-May	6 - 20	9	9	8	9	8
8-Jun	6 - 20	10	10	9	7	9
12-Jun	6 - 20	12	13	9	6	8
19-Jun	6 - 20	17	17	14	16	13
26-Jun	6 - 20	16	15	17	23	15
6-Jul	6 - 20	12	13	13	18	12
10-Jul	6 - 20	6	7	7	13	8
20-Jul	6 - 20	7	9	10	9	11
24-Jul	6 - 20	9	12	12	12	15
31-Jul	6 - 20	10	10	9	12	19
7-Aug	6 - 20	9	9	11	10	10
17-Aug	6 - 20	9	11	12	8	9

Table 10. Boron concentration (%) in onion root tissue for five fertigation treatments. Malheur Experiment Station, Oregon State University, Ontario, OR, 2015.

		Treatment				
Date	Sufficiency range	1	2	3	4	5
29-May	19 - 60	15	22	14	16	14
8-Jun	19 - 60	46	48	54	54	45
12-Jun	19 - 60	45	52	21	28	23
19-Jun	19 - 60	29	36	31	33	41
26-Jun	19 - 60	25	41	42	39	35
6-Jul	19 - 60	28	37	48	37	37
10-Jul	19 - 60	29	27	26	28	30
20-Jul	19 - 60	24	24	24	23	30
24-Jul	19 - 60	27	30	33	25	38
31-Jul	19 - 60	26	24	23	27	35
7-Aug	19 - 60	22	18	25	23	22
17-Aug	19 - 60	22	20	24	22	31

Table 11. Nutrients[a] applied (lb/acre) to onions through drip tape during the season for five fertigation treatments. Malheur Experiment Station, Oregon State University, Ontario, OR, 2015.

	Treatment																				
	1	2										3									
Date	N	N	P	K	S	Ca	Zn	Mg	Mn	Cu	B	N	P	K	S	Ca	Zn	Mg	Mn	Cu	B
4-Jun	40	23										23		1	4				0.3		0.2
10-Jun	20	40										40							0.3		
16-Jun	20	20																	0.5		
23-Jun	20	20													15				0.5	0.3	
29-Jun		20												5					0.3		
7-Jul		20		10															0.3		
13-Jul				30																	
21-Jul				10																	
29-Jul			10	10																	
4-Aug			10	25				2.0						25							
11-Aug			10	20				2		0.3	0.2										
Total	100	143	30	105	0	0	0	4	0	0.3	0.2	63	0	31	19	0	0	0	2.2	0.3	0.2

	Treatment																				
	4											5									
Date	N	P	K	S	Ca	Zn	Mg	Mn	Cu	B	N	P	K	S	Ca	Zn	Mg	Mn	Cu	B	
4-Jun	23		3	2				0.3		0.2	23	10								0.2	
10-Jun	40										40							0.3			
16-Jun	20							0.3			20										
23-Jun	20			15		0.3		0.5	0.3		20			26			2.0				
29-Jun	20		5					0.3			20						2.0				
7-Jul	20							0.3			20		10				2.0	0.3			
13-Jul			30										30								
21-Jul													10								
29-Jul													10								
4-Aug													25								
11-Aug			20						0.3			10	20				2				
Total	143	0	58	17	0	0.3	0	1.7	0.6	0.2	143	20	105	26	0	0	8	0.6	0	0.2	

[a]N: Urea ammonium nitrate solution 32-0-0.
P: NUE 0-30-0 (Bio-Gro, Mabton, WA).
K: NUE Special K24 0-0-24 (Bio-Gro, Mabton, WA).
Mg: Magnesium Dextro-Lac 3%, Agro K Corp., Minneapolis, MN.
Mn: Che-Man 5%, PHT, J.R. Simplot Co., Boise, ID.
Zn: System-Zn 8%, Agro K Corp., Minneapolis, MN.
Cu: Copper Dextro-Lac 4%, Agro K Corp., Minneapolis, MN.
B: Concept Boron 10%, Ag Concept Corp., Bliss, ID.

Table 12. Weekly soil solution analyses for five fertigation treatments. Data represent the amount of each plant nutrient per day that the soil can potentially supply to the crop. Numbers following each nutrient are the critical levels. Malheur Experiment Station, Oregon State University, Ontario, OR, 2015.

	N Critical	N, variable					P, 0.7 lbs					K, 8 lbs					S, 3 lbs					Ca, 3 lbs				
Date	level, lb/acre	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
		lb/day																								
29-May	8.0	6.0	4.3	3.9	3.4	4.3	1.2	0.9	0.8	0.8	1.0	8.6	7.6	7.9	7.6	10.5	2.9	2.6	2.4	2.7	2.2	3.9	3.7	3.7	3.9	3.8
8-Jun	7.5	6.9	5.6	6.9	6.4	6.9	2.6	3.0	3.5	3.4	3.8	17.9	18.1	17.8	18.9	21.4	13.0	11.2	10.5	15.4	15.0	7.1	7.0	6.2	7.0	6.9
12-Jun	6.0	7.3	8.1	8.1	6.9	9.0	1.0	0.9	1.2	1.2	1.1	9.0	9.2	13.2	9.9	9.7	5.1	4.8	4.8	4.9	5.4	5.4	5.3	5.5	5.2	5.7
19-Jun	5.5	17.6	21.9	9.4	15.9	16.7	1.4	0.9	1.1	0.8	0.5	19.1	10.1	12.3	9.9	6.5	1.8	3.2	0.9	0.8	0.7	5.2	6.4	5.4	5.4	5.0
26-Jun	5.0	12.4	12.0	13.7	12.9	12.0	0.6	0.7	0.8	0.7	0.7	7.3	7.6	7.9	7.8	7.6	2.8	2.9	3.1	3.2	2.8	4.2	4.0	4.1	4.2	4.1
6-Jul	4.5	23.6	18.4	9.4	20.6	15.9	1.6	1.8	2.3	2.1	2.7	9.8	10.4	9.7	10.5	10.0	5.2	2.6	3.0	3.2	4.2	6.8	6.5	6.3	6.4	6.3
10-Jul	4.0	11.6	11.1	10.7	13.3	15.9	1.2	1.3	1.8	1.6	2.1	7.3	6.2	8.4	6.4	8.7	4.6	2.6	3.7	3.5	9.6	5.5	6.1	5.3	5.4	5.7
20-Jul	3.0	14.1	18.0	15.4	15.9	23.1	1.0	1.0	1.5	1.2	1.9	9.6	8.5	10.0	8.5	10.2	3.9	3.0	3.0	3.6	7.0	5.6	5.7	5.4	5.6	5.3
24-Jul	2.0	14.1	18.9	13.7	14.1	25.3	1.5	2.3	2.0	1.9	2.5	10.8	9.1	9.5	8.3	8.9	4.8	3.7	4.2	4.9	9.0	5.1	4.6	4.9	4.4	4.7
31-Jul	1.0	12.9	17.1	21.9	11.6	17.6	1.7	2.0	2.3	1.0	1.5	8.7	8.8	7.0	8.4	7.1	5.7	4.0	4.2	5.9	5.5	4.8	3.8	4.4	4.7	4.5
7-Aug	0.5	12.4	17.1	18.0	12.9	19.7	1.1	1.5	1.2	1.3	1.5	5.8	5.7	8.7	5.4	6.2	6.4	5.9	5.3	7.0	6.2	5.0	4.5	4.1	4.5	5.1
17-Aug	0.5	21.0	26.1	29.1	20.6	29.1	1.5	1.7	1.6	1.8	1.2	4.1	6.3	7.7	6.5	6.7	5.2	6.3	6.7	8.5	7.6	4.0	5.3	5.1	5.9	7.6
Avg.		13.3	14.9	13.4	12.9	16.3	1.4	1.5	1.7	1.5	1.7	9.8	9.0	10.0	9.0	9.5	5.1	4.4	4.3	5.3	6.3	5.2	5.2	5.0	5.2	5.4

	Mg, 2 lbs					Zn, 1 oz					Mn, 1 oz					Cu, 0.4 oz				
Date	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
	lb/day					oz/day														
29-May	9.2	8.0	8.3	8.4	9.9	1.7	1.7	1.7	1.6	1.7	0.9	0.6	0.6	0.5	0.7	0.6	0.6	0.5	0.5	0.4
8-Jun	18.7	16.8	15.7	18.5	19.1	6.0	6.0	6.0	6.0	6.0	0.7	0.5	0.8	1.1	1.0	5.0	2.0	6.0	3.0	2.0
12-Jun	11.3	10.9	13.3	11.0	11.7	2.1	2.0	2.1	2.4	1.9	0.3	0.3	0.4	0.4	0.2	0.4	0.3	0.4	0.5	0.3
19-Jun	6.3	8.1	6.0	5.6	4.0	0.7	1.2	1.0	0.9	1.3	0.2	0.4	0.3	0.2	0.3	0.3	0.2	0.2	0.3	0.2
26-Jun	8.8	8.7	9.0	9.2	8.7	1.1	1.5	1.6	1.5	1.4	0.5	0.5	0.6	0.6	0.5	0.3	0.4	0.4	0.4	0.4
6-Jul	15.1	13.3	13.8	12.0	14.2	4.2	4.2	4.6	4.8	4.5	0.4	0.4	0.5	0.6	0.6	0.8	0.9	0.7	1.0	0.7
10-Jul	11.8	10.2	10.6	9.6	11.6	3.6	3.5	4.0	3.9	4.0	0.5	0.4	0.6	0.5	0.7	0.4	0.6	0.6	0.7	0.5
20-Jul	9.6	10.6	9.8	10.6	9.7	1.8	3.4	2.8	3.4	3.0	0.9	0.7	0.9	0.9	1.0	0.3	0.8	0.9	1.0	0.7
24-Jul	9.8	8.1	9.1	8.9	8.8	2.0	3.2	2.1	4.0	3.7	0.7	0.5	0.7	0.7	0.8	0.3	0.6	0.6	0.8	0.6
31-Jul	10.4	9.3	8.1	9.4	8.4	2.4	2.8	2.8	3.4	3.2	0.4	0.4	0.6	0.5	0.6	0.4	0.5	0.5	0.6	0.6
7-Aug	8.8	7.6	7.1	7.7	9.2	3.5	3.6	2.4	4.9	2.6	0.6	0.5	0.9	0.7	0.8	0.5	0.4	0.5	0.3	0.5
17-Aug	6.8	8.1	7.9	8.5	12.9	1.9	4.8	3.2	5.0	3.8	0.9	0.7	1.1	1.0	1.2	0.7	0.6	0.7	0.4	0.6
Avg.	10.6	10.0	9.9	10.0	10.7	2.6	3.2	2.9	3.5	3.1	0.6	0.5	0.7	0.6	0.7	0.8	0.7	1.0	0.8	0.6

Table 13. Soil available N (nitrate-N plus ammonium-N, lb/acre) in top foot of soil for five treatments during the season measured from weekly soil samples. Malheur Experiment Station, Oregon State University, Ontario, OR, 2015.

	Treatment				
Date	1	2	3	4	5
29-May	42	30	27	24	30
8-Jun	48	39	48	45	48
12-Jun	51	57	57	48	63
19-Jun	123	153	66	111	117
26-Jun	87	84	96	90	84
6-Jul	165	129	66	144	111
10-Jul	81	78	75	93	111
20-Jul	99	126	108	111	162
24-Jul	99	132	96	99	177
31-Jul	90	120	153	81	123
7-Aug	87	120	126	90	138
17-Aug	147	183	204	144	204
Average	93	104	94	90	114

Table 14. Onion yield response to in-season nutrient supplementation strategies for two varieties. Malheur Experiment Station, Oregon State University, Ontario, OR, 2015.

		Total yield	Marketable yield by grade								Maturity on August 4			
Variety	Treatment		Total	>4¼ in	4-4¼ in	3-4 in	2¼-3 in	Small	No. 2s	Bulb counts >4¼ in	Total rot	Tops down	Leaf dryness	IYSV
		---------- cwt/acre ----------								#/50 lb	---------- % ----------			0 - 5
Vaquero	1	1118.3	1108.8	27.7	406.3	658.7	16.0	2.3	0.0	32.3	0.6	38.3	28.3	1
	2	1119.8	1108.9	50.1	395.7	640.8	22.3	3.5	0.0	32.0	0.6	36.7	28.3	1
	3	1120.9	1101.4	49.2	385.9	650.8	15.5	4.0	0.0	32.2	1.4	35.0	26.7	1
	4	1090.8	1071.8	24.0	345.6	681.5	20.7	6.0	0.0	32.5	1.2	35.0	26.7	1
	5	1116.3	1101.1	50.4	439.8	593.9	17.0	7.4	0.0	31.8	0.7	40.0	28.3	1
	average	1113.2	1098.4	40.3	394.7	645.1	18.3	4.6	0.0	32.2	0.9	37.0	27.7	1
Avalon	1	1252.6	1111.6	130.7	492.7	474.4	13.8	4.7	0.0	30.4	11.2	75.0	23.3	1
	2	1228.2	1100.3	98.7	467.3	515.6	18.7	4.5	0.0	31.3	10.2	75.0	21.7	1
	3	1204.3	1068.1	87.3	440.5	520.8	19.6	5.2	0.0	29.4	11.0	73.3	26.7	1
	4	1222.3	1100.7	121.7	472.7	489.4	16.8	5.9	0.0	31.0	9.4	66.7	23.3	1
	5	1190.0	1033.5	71.7	431.3	514.4	16.1	4.0	0.0	31.4	12.9	73.3	25.0	1
	average	1219.5	1082.8	102.0	460.9	502.9	17.0	4.9	0.0	30.7	10.9	72.7	24.0	1
Average	1	1185.4	1110.2	79.2	449.5	566.6	14.9	3.5	0.0	31.3	5.9	56.7	25.8	1
	2	1174.0	1104.6	74.4	431.5	578.2	20.5	4.0	0.0	31.7	5.4	55.8	25.0	1
	3	1162.6	1084.8	68.2	413.2	585.8	17.6	4.6	0.0	30.8	6.2	54.2	26.7	1
	4	1156.6	1086.3	72.9	409.2	585.4	18.8	5.9	0.0	31.8	5.3	50.8	25.0	1
	5	1153.1	1067.3	61.0	435.5	554.1	16.6	5.7	0.0	31.6	6.8	56.7	26.7	1
	average	1166.4	1090.6	71.2	427.8	574.0	17.7	4.7	0.0	31.4	5.9	54.8	25.8	1
LSD (0.05)														
Treatment		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Variety		33	NS	29.1	40	41.2	NS	NS	NS	NS	1.4	2.8	2.0	NS
Treatment X Variety		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS