ONION (*Allium cepa* 'Redwing', 'Tamara', and 'Legend')
Pink root; *Setophoma terrestris*
Host response; mycorrhizal colonization

Lindsey J. du Toit, Michael L. Derie, Barbara J. Holmes, C. Erin Miller, and Louisa R. Brouwer (née Winkler), Washington State University Mount Vernon NWREC, Mount Vernon, WA 98273; and Timothy D. Waters, and Jennifer Darner, Washington State University Benton/Franklin Co. Extension, Pasco, WA 99301.

Effects of the arbuscular mycorrhizal fungi inoculant Mykos Gold Granular on pink root and yield in onion bulb crops near Irrigon, OR, 2017.

Symbiotic arbuscular mycorrhizal fungi (AMF) form associations with most crop species. By enabling hosts plants to mine the soil for immobile nutrients (particularly phosphorus, P) and enhancing resistance to some biotic and abiotic stresses, AMF potentially could reduce the rate of chemical inputs needed in some production systems. Onions are particularly responsive to AMF because of the relatively unbranched root structure and scant root hairs. Trials were carried out in the semi-arid Columbia Basin of northcentral Oregon, a major region of onion production for the USA, to test the potential effects of an AMF inoculant, Mykos Gold Granular (RTI-Ag, Gilroy, CA), on onion production. The trials were planted in center-pivot-irrigated, commercial onion bulb fields near Irrigon, OR. The AMF inoculant was evaluated in four fields, each of which represented one replicate of a randomized complete block design. Each replicate rated included two adjacent, 44-in. wide beds extending the length of the field, one treated and the other not treated with Mykos Gold Granular. Each bed consisted of two double-rows of onions. Higher application rates of soluble fertilizers, especially P, can inhibit association of AMF with plant roots. Therefore, the effect of a pre-plant, banded fertilizer application on the Mykos Gold Granular treatment was tested in two of the fields (replicates), as a 2-by-2 factorial treatment combination: with and without AMF inoculant, each with and without pre-plant, banded fertilizer application. Each of the four treatment combinations was rated along the length of one bed. Mykos Gold Granular was applied in-furrow at planting at a rate of 6.6 lb/A. Details of the proprietary, pre-plant, banded fertilizer application were not provided by the grower. Two of the four fields were planted with seed of the onion cv. Redwing, one field was planted with Tamara, and the fourth field with Legend. All seed was treated with FarMore 500 (metalaxyl + fludioxonil + azoxystrobin + spinosad + thiamethoxam; Syngenta USA, Greensboro, NC). Most data were collected from five locations equally spaced along a 1,000 ft section of each plot, except stand counts which were taken at eight locations per plot. Data were averaged over subsamples in each plot. The 50- to 125-A onion crops in the four fields were planted between 14 and 27 Mar, with each field planted on a single day. Onion stands were counted from each of four 10-ft sections of bed per sampling location (1- to 3-true leaf stage). Soil was sampled from each plot on 4 May (6-in. depth) for nutrient analysis. On 15 Jun, 5 onion plants were dug from each sampling location. The roots were cut, washed, stained (Verheilig et al. 1998), and examined microscopically (5× to 20× magnification) to quantify AMF colonization for each of 40 root sections per plant based on a modified gridline intersection method (Giovannetti and Mosse 1980). For the same plants, leaf length was measured, and the bulbs and leaves dried and weighed. The dried leaves and bulbs were submitted to SoilTest Farm Consultants (Moses Lake, WA) for nutrient analysis. On 17 Aug, all the onion bulbs in a 5-ft section of the bed were dug from five sampling locations per plot. The roots were rinsed in water and rated for severity of pink root (% of roots with symptoms, averaged for all bulbs sampled in a plot). Tops were cut 2 in. above each bulb, and the bulbs weighed and graded (colossal = >4.00 in. diameter, jumbo = 3.00-4.00 in., medium = 2.25-3.00 in., prepack <2.25 in., and rejected bulbs = bulbs with split basal plates, rot, bolting, or green shoulders). Data from all four fields were evaluated for effects of Mykos Gold Granular by single-factor analyses of variance (ANOVAs), and data from fields with the 2-by-2 factorial design were evaluated for Mykos Gold Granular and fertilizer effects by two-factor ANOVAs, using R Version 3.1.1.

Results of the single-factor experiment (with and without Mykos Gold Granular) are in Table 1. In-furrow application of Mykos Gold Granular was not associated with any statistically significant changes in onion crop growth (stand count, leaf length, and dry biomass), pink root severity, or yield. Analysis of the two-factor experiment (with and without Mykos Gold Granular, and with and without a pre-plant, banded fertilizer application) identified no significant interaction between AMF and fertilizer treatments. Results organized by the two main effects are in Table 2. Leaf length, dry biomass, number and weight of jumbo bulbs, and total marketable bulb weight were all significantly greater in plots with the pre-plant, banded fertilizer application than in control plots. The growth-enhancing effects of this fertilizer treatment were expected given the relatively low soil nutrient status in these fields prior to planting (Olsen P of 26-30 ppm, and total N of 83-110 lb/A). The absence of a significant AMF effect could be due to failure of Mykos Gold Granular to induce a significant increase in AMF colonization of onion roots. Although this inoculant induced AMF root colonization in growth chamber tests in other studies (Knerr et al. 2016), root colonization rates were similar in Mykos Gold Granular-inoculated and control plots in this study, demonstrating the presence of endemic AMF in the fields. The seed treatment FarMore FI500 contains azoxystrobin in Fungicide Resistance Action Committee Group 11, which can have a negative effect on true fungi such as AMF (Diedhiou et al. 2004), potentially limiting the benefits of Mykos Gold Granular and native AMF. Root colonization by AMF was less extensive in plots that received the pre-plant, banded fertilizer application (73%) than in control plots (82%). This is consistent with results in similar field trials on other farms in the Columbia Basin (Henrichs et al. 2017; du Toit et al. 2018). This study offers no evidence of benefits from applying AMF inoculants such as Mykos Gold Granular in spring-planted, direct-seeded onion bulb crops grown using practices typical of the semi-arid Columbia Basin.

Table 1.

Crop attribute	Control	Mykos Gold Granular
Onion stand count on 18 Apr (plants/40 ft of double-row)	195 ± 4[z]	198 ± 4
Leaf length on 15 Jun (in.)[y]	24.84 ± 0.48	24.16 ± 0.44
Biomass on 15 Jun (oz dry weight)[x]	0.809 ± 0.055	0.814 ± 0.053
AMF root colonization (%)	70 ± 5	68 ± 4
Pink root severity (% per bulb)	8 ± 1	9 ± 1
Colossal bulb weight (lb)[w]	0.0 ± 0.0	0.0 ± 0.0
Jumbo bulb weight (lb)[w]	19.9 ± 1.4	20.7 ± 1.9
Medium bulb weight (lb)[w]	6.3 ± 0.7	6.2 ± 0.7
Prepack bulb weight (lb)[w]	0.2 ± 0.0	0.2 ± 0.0
Total marketable bulb weight (lb)[w]	26.4 ± 1.0	27.0 ± 1.4
Weight per bulb (lb)[w]	0.57 ± 0.02	0.57 ± 0.02
Colossal bulb number[w]	0 ± 0	0 ± 0
Jumbo bulb number[w]	30 ± 2	31 ± 2
Medium bulb number[w]	15 ± 2	15 ± 2
Prepack bulb number[w]	1 ± 0	1 ± 0
Total number of marketable bulbs[w]	46 ± 1	47 ± 2
Foliar N (%)	3.52 ± 0.17	3.46 ± 0.16
Foliar P (%)	0.46 ± 0.02	0.45 ± 0.02
Foliar K (%)	3.63 ± 0.16	3.49 ± 0.23
Foliar Ca (%)	1.57 ± 0.09	1.56 ± 0.1
Foliar Mg (%)	0.41 ± 0.03	0.40 ± 0.03
Foliar S (%)	0.48 ± 0.02	0.43 ± 0.02
Foliar Zn (%)	27 ± 2	24 ± 2
Foliar Fe (ppm)	522 ± 53	461 ± 33
Foliar Mn (ppm)	43 ± 4	41 ± 5
Foliar Cu (ppm)	13 ± 1	12 ± 1
Foliar B (ppm)	30 ± 2	28 ± 2
Foliar Na (ppm)	0.16 ± 0.05	0.14 ± 0.04

[z] Most values represent the average of four replications. The exception is AMF root colonization data collected from two of the four replicates (fields). All plots were treated with a pre-plant, banded application of fertilizer. No significant differences were detected between Mykos Gold Granular-inoculated and non-inoculated plots for any of the variables measured ($p < 0.05$).

[y] Average of five plants per sampling location per replicate (field).

[x] Dry weight of leaves from five plants per sampling site per replicate (field).

[w] Per 5 ft of bed on 17 Aug.

Table 2.

Crop attribute	AMF treatment		AMF effect[y]	Pre-plant, banded fertilizer		Fertilizer effect[y]
	Control	Mykos Gold Granular		None	Standard	
Onion stand count on 18 Apr (plants/40 ft of double-row)	204 ± 2[z]	208 ± 2	ns	205 ± 2	207 ± 2	ns
Leaf length on 15 Jun (in.)[x]	23.36 ± 0.44	23.12 ± 0.48	ns	22.32 ± 0.40	24.16 ± 0.44	***
Biomass on 15 Jun (oz dry weight)[w]	0.709 ± 0.063	0.709 ± 0.065	ns	0.620 ± 0.056	0.798 ± 0.065	*
AMF root colonization (%)	77 ± 3	79 ± 3	NA	82 ± 1	73 ± 3	NA
Pink root severity (% per bulb)	8 ± 1	8 ± 1	ns	8 ± 1	8 ± 1	ns
Colossal bulb weight (lb)[v]	0.1 ± 0.1	0.0 ± 0.0	ns	0.1 ± 0.1	0.0 ± 0.0	NA
Jumbo bulb weight (lb)[v]	15.4 ± 1.0	15.0 ± 1.1	ns	13.7 ± 1.2	16.6 ± 0.8	*
Medium bulb weight (lb)[v]	8.1 ± 0.8	9.2 ± 0.6	ns	8.8 ± 0.8	8.5 ± 0.6	ns
Prepack bulb weight (lb)[v]	0.3 ± 0.1	0.2 ± 0.1	ns	0.3 ± 0.1	0.2 ± 0.1	NA
Total marketable bulb weight (lb)[v]	23.8 ± 0.6	24.4 ± 0.8	ns	22.8 ± 0.7	25.4 ± 0.6	**
Weight per bulb (lb)	5.18 ± 0.12	4.93 ± 0.12	ns	0.50 ± 0.01	0.52 ± 0.01	ns
Colossal bulb number[v]	0 ± 0	0 ± 0	ns	0 ± 0	0 ± 0	NA
Jumbo bulb number[v]	25 ± 2	25 ± 2	ns	22 ± 2	27 ± 1	*
Medium bulb number[v]	20 ± 2	23 ± 2	ns	22 ± 2	21 ± 1	ns
Prepack bulb number[v]	2 ± 0	2 ± 0	ns	2 ± 0	2 ± 0	NA
Total number of marketable bulbs[v]	46 ± 1	49 ± 1	ns	46 ± 1	49 ± 1	ns
Foliar N (%)	3.58 ± 0.11	3.47 ± 0.12	ns	3.56 ± 0.12	3.49 ± 0.11	ns
Foliar P (%)	0.44 ± 0.01	0.42 ± 0.01	ns	0.41 ± 0.01	0.45 ± 0.01	**
Foliar K (%)	3.63 ± 0.14	3.45 ± 0.16	ns	3.52 ± 0.16	3.56 ± 0.14	ns
Foliar Ca (%)	1.53 ± 0.06	1.53 ± 0.07	ns	1.49 ± 0.06	1.56 ± 0.07	ns
Foliar Mg (%)	0.40 ± 0.02	0.40 ± 0.02	ns	0.40 ± 0.02	0.40 ± 0.02	ns
Foliar S (%)	0.48 ± 0.02	0.44 ± 0.02	*	0.47 ± 0.02	0.45 ± 0.02	ns
Foliar Zn (%)	26 ± 1	24 ± 1	ns	25 ± 1	25 ± 1	ns
Foliar Fe (ppm)[u]	517 ± 48	482 ± 34	ns	508 ± 51	491 ± 31	ns
Foliar Mn (ppm)[u]	40 ± 3	40 ± 3	ns	38 ± 3	42 ± 3	ns
Foliar Cu (ppm)	13 ± 0	13 ± 0	ns	13 ± 1	13 ± 0	ns
Foliar B (ppm)	27 ± 1	26 ± 1	ns	24 ± 1	29 ± 1	***
Foliar Na (ppm)[u]	0.15 ± 0.03	0.16 ± 0.04	ns	0.13 ± 0.03	0.15 ± 0.03	ns

[z] Most values represent averages across two fields (= replications). The exception is AMF root colonization which was measured for plant roots sampled from only one of the two fields.

[y] Variables for which a significant main effect of AMF or fertilizer were detected are highlighted in bold and identified as follows: * means $0.01 \leq p \leq 0.05$, ** means $0.001 \leq p < 0.01$, *** means $p < 0.001$; ns = the treatment effect was not significant, NA = data were not analyzed owing to predominance of zero-values or, in the case of root colonization data, lack of replication among fields (only measured in one of two fields that had the 2-by-2 factorial treatment design).

[x] Average of five plants per sampling location per plot in each field.

[w] Dry weight of leaves from five plants per sampling location per plot in each field.

[v] Per 5 ft of bed at each of five sampling locations per plot in each field on 17 Aug.

[u] Square-root transformed for statistical analysis.