

ONION (*Allium cepa* '6672')
Pink root; *Setophoma terrestris*
Host response; mycorrhizal colonization

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Effects of three arbuscular mycorrhizal fungi inoculants on pink root and yield in an onion crop near Othello, WA, 2017.

Symbiotic arbuscular mycorrhizal fungi (AMF) form associations with most crop species. By enabling host 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. This study evaluated AMF inoculants in the context of intensive onion production systems in the semi-arid Columbia Basin of central Washington and northcentral Oregon States, a major region of onion production for the USA. Three AMF inoculants were compared to a non-inoculated control treatment in a drip-irrigated, commercial onion bulb field. Each AMF product was added to the planter box with the onion seed and applied at planting. Application rates were based on spore concentration and compatibility of each product using the grower's equipment. The products and application rates tested included: AGTIV Specialty Crops Powder (AGTIV, Rivière du Loup, Quebec), 0.4 g per 1,000 seeds = 4,800 viable spores per 1,000 seeds; MycoApply Ultrafine Granular (Mycorrhizal Applications, Inc., Grants Pass, OR), 0.2 g per 1,000 seeds = 57 propagules per 1,000 seeds; Mykos Gold Granular (RTI-Ag, Gilroy, CA), 0.6 g per 1,000 seeds = 180 propagules per 1,000 seeds. The trial design was a randomized complete block with four replicates. A block consisted of four plots, each of which was randomly assigned to one AMF product or the non-inoculated control treatment. One plot was a 44 in.-wide bed extending the full length of the field (approximately 800 m). A bed contained a double-row of onions on both sides of a line of drip tape that was centered in the bed. Onion variables were measured at two locations per plot. The trial was planted on 17 Apr using seed of the onion cv. 6672. The entire field was treated with Lorsban insecticide (Dow AgroSciences, Indianapolis, IN) and fertilized according to the grower's standard program. Onion stand counts, consisting of the number of plants measured in each of four 10-ft sections near the center of each plot, were taken on 25 May when seedlings were at the 2- to 3-true-leaf stage. Five randomly selected plants per sampling location were dug up carefully on 29 Jun at the 7- to 8-true-leaf stage, and the length of the tallest leaf measured. Onion dry biomass (total mass of bulb and leaves of five plants per location) was measured after cutting off the roots and drying the plants at 120°F. Onion bulb harvest and pink root assessments were completed on 15 Aug by digging up all bulbs in 5 ft length of bed per plot. The roots were rinsed in water and rated for severity of pink root (percentage of roots on each plant with symptoms), averaged for all bulbs per plot. Onion tops were cut 2 in. above the bulb, after which the bulbs were weighed and graded (colossal bulbs >4.00 in. diameter; jumbo bulbs 3.00-4.00 in.; medium bulbs 2.25-3.00 in.; prepack bulbs <2.25 in.; and rejected bulbs with split basal plates, rot, bolting, or green shoulders). All statistical tests were completed using R version 3.3.1. Data were evaluated for AMF product effects by single-factor analysis of variance (ANOVA) followed by Dunnett's test to compare each AMF treatment to the control treatment, with the alpha (α) significance set at $p < 0.017$ (adjusted according to the Bonferroni correction to preserve a family-wise α of 0.05; tests were carried out using the R package 'multcomp').

Most of the onion characteristics measured in this field trial were similar across all four treatments, with no evidence of a significant effect of any of the AMF inoculants on onion growth or root health. Only the number and weight of medium-sized bulbs differed among AMF treatments, with significantly fewer medium bulbs and less weight of medium bulbs in plots treated with AGTIV Specialty Crops Powder and MycoApply Ultrafine Granular than in the control plots. Medium bulb weight was 2.6, 2.5, and 4.4 lb in AGTIV, MycoApply, and control plots, respectively ($p = 0.037$); medium bulb numbers were 6, 7, and 12 ($p = 0.013$). Control plots also tended to yield more colossal bulbs than plots with any other treatment, although the differences were not significant statistically. Pink root was not particularly severe in this trial (4.95%), with no significant difference for plots with any of the AMF treatments compared to that of the control plots. In 2016, AMF products were compared on the same farm in two fields: one trial in a drip-irrigated field planted with the onion cv. Arcero, and a trial in a drip-irrigated field with the cv. 16000 (Henrichs et al. 2017). In both trials, Mykos Gold Liquid and MycoApply Endo Liquid were applied to the soil in plots that received either the normal rate (1 \times) or half-rate (0.5 \times) of a pre-plant, banded fertilizer application typically used on that farm. Mykos Gold Liquid did not increase AMF root colonization rates relative to the control treatment in either trial, regardless of the rate of pre-plant, banded fertilizer application, but MycoApply Endo Liquid did result in significantly more AMF root colonization compared to control plots (29.5 vs. 18.1%) in the 0.5x fertilizer treatment in the field with Arcero. This difference was not detected in the 1.0x fertilizer treatment, suggesting that the higher rate of fertilizer had a slightly inhibitory effect on root colonization by AMF. Regardless, an 11% increase in degree of AMF root colonization in the MycoApply plots did not affect severity of pink root, bulb yield (total marketable yield or size distribution of bulbs), or bulb quality (firmness) (Henrichs et al. 2017). Results from this study suggest there was no benefit to applying these commercial AMF inoculants to onion crops under the production practices utilized on this farm, which included drip irrigation, application of crop protection products (fungicides, insecticides, and herbicides) and synthetic (i.e., highly soluble) fertilizers. AMF inoculants may provide a benefit in situations in which soil biological activity is needed to make nutrients available to plants by releasing them from complex organic molecules (non-soluble fertilizers); and/or where plants are subjected to greater biotic and/or abiotic stresses such as soilborne pathogens and moisture stress.

Onion crop attribute	Control	AGTIV	MycoApply	Mykos Gold Granular	Pr (>F) ^z	Transformation ^y
Stand count on 25 May (plants per 40 ft of bed)	426 ± 4 ^x	428 ± 5	430 ± 4	426 ± 6	0.761	-
Leaf length on 29 Jun (in) ^w	22.08 ± 1.39	21.95 ± 0.6	21.62 ± 0.84	21.71 ± 0.68	0.935	-
Dry plant biomass on 29 Jun (oz) ^v	0.53 ± 0.07	0.49 ± 0.04	0.49 ± 0.05	0.53 ± 0.04	0.443	-
Pink root severity (% per bulb)	5 ± 1	5 ± 1	5 ± 1	5 ± 1	0.939	-
Colossal bulb weight (lb) ^u	5.4 ± 1.7	4.8 ± 1.4	3.8 ± 1.1	3.6 ± 0.7	0.617	-
Jumbo bulb weight (lb) ^u	27.4 ± 3.1	29.8 ± 1.8	32.1 ± 1.1	28.4 ± 1.6	0.266	-
Medium bulb weight (lb) ^u	4.4 ± 0.5	2.6 ± 0.8 ^{*t}	2.5 ± 0.6 [*]	3.8 ± 0.7	0.037	-
Total marketable bulb weight (lb) ^u	37.8 ± 1.4	37.5 ± 1.6	38.5 ± 0.4	36.2 ± 1.4	0.521	-
Total bulb weight (lb) ^u	38.5 ± 1.3	38.6 ± 1.5	38.9 ± 0.4	36.9 ± 1.4	0.525	-
Colossal bulb number ^u	5 ± 1	4 ± 1	3 ± 1	3 ± 1	0.664	-
Jumbo bulb number ^u	36 ± 3	37 ± 2	41 ± 2	38 ± 1	0.231	-
Medium bulb number ^u	12 ± 1	6 ± 1 [*]	7 ± 1 [*]	10 ± 2	0.013	Log
Total number of marketable bulbs ^u	54 ± 2	49 ± 1	52 ± 2	53 ± 2	0.157	-
Total number of bulbs ^u	55 ± 2	51 ± 1	53 ± 2	54 ± 2	0.218	√

^z Probability values associated with the AMF main effect in the global ANOVA.

^y Where appropriate, data were transformed to meet assumptions of parametric analysis. “Log” = logarithm, “√” = square root, and “-” indicates no transformation.

^x Each value is the mean ± standard error of the mean.

^w Average of five plants.

^v Dry weight of leaves and bulbs from five plants.

^u Bulbs harvested from 5 feet of bed.

^t * = Treatment mean was significantly different ($p < 0.017$) from that of the non-inoculated control plots.