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Influence of organic groundcovers on mycorrhizal colonization and symbiosis of organically managed fruit crops

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Undergraduate Research Articles

Influence of organic groundcovers on mycorrhizal colonization and symbiosis of organically managed fruit crops

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ABSTRACT

Ground covers have the potential to impact the crop rhizosphere biology, which includes organisms such as arbuscular mycorrhizal fungi (AMF), which in turn affect the crop host plant through symbiosis. There has been evidence that a ground cover that provides a suitable environment for colonization of AMF and subsequent symbiosis could be a tool in organic fruit production. The objective of this research was to compare colonization of AMF in strawberry plant (*Frageria x ananassa* cv. Radiance) and apple rootstocks (*Malus x domestica*, cv. M. 26) grown in a greenhouse affected by various ground cover treatments. Inoculation was achieved by mixing BioOrganics™ Endomycorrhizal Inoculant directly into soilless media according to label rates. Following a dormancy period, plants were treated with one of the following ground cover treatments: 1) city-generated urban green-compost (GC), 2) shredded white paper, 3) urban refuse wood chips or 4) an untreated control. The GC ground cover significantly increased percent colonization of AMF compared to other ground covers; however, AMF infection did not affect plant biomass, root volume, root surface area, root diameter, or leaf area. The AMF suppressed root length; plants inoculated with AMF had shorter roots but similar root volume to compared to non-inoculated plants. The GC treatment may have disproportionately contributed more nutrition by media composition of a smaller particle size and a decreased lignin, cellulose, and hemicellulose content compared to other ground cover treatments. Though the ground covers in this study had no effect on symbiotic AMF benefits, long-term studies with mature host plants could reveal a correlation between ground cover media and symbiosis.

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MEET THE STUDENT-AUTHOR

Raven Anai Bough

I am a proud native of Fayetteville, Arkansas and graduated from Fayetteville High School in 2009. The following fall semester, I began studying Horticulture at the University of Arkansas. To gain supplemental skills and experience necessary for a career in research, I also pursued a minor in biology, worked as a lab-assistant for the Department of Horticulture, worked at a local plant nursery and retail center, and completed an internship funded by the National Science Foundation Research Experience for Undergraduates at the non-profit Donald Danforth Plant Science Center. Another research project I conducted in addition to the following study was a team effort entitled "Herbicide-Resistant Soybeans in Arkansas: Lessons Learned and Future Direction," where I focused on crop science issues and implications.

I plan to attend graduate school in California, the heart of United States fruit production, to pursue a career in horticultural plant breeding for crop improvement. Ultimately, I hope to attain a Ph.D. and manage my own laboratory and research programs in either a university or industry setting.

INTRODUCTION

In the past decade, both the total market value of organic fresh fruits and vegetables and the extent of organic cropland have nearly tripled (Greene, 2012). Public concern over chemical nonpoint source pollution from agriculture runoff, the leading cause of negative water quality impacts (EPA, 2012), has been a factor in rising consumer demand for organic products. The USDA Certified organic weed management programs must utilize non-synthetic chemical herbicide weed control methods due to strict regulations created by the National Organic Program (CPWDMPS, 2013).

Organic ground covers are a useful tool in organic production to physically suppress weeds with minimal or no additional herbicide input. Other advantages include erosion protection, increased water infiltration and availability, soil temperature regulation, and supplemental nutrition through the decomposition of organic matter (Pinamonti, 1998). Organic ground covers have the potential to alter the rhizosphere of a crop, including arbuscular mycorrhizal fungi (AMF), because of direct contact with the soil and decomposition over time. The AMF form a symbiotic relationship with a host plant in which fungi receive plant-produced carbohydrates and host plants are provided with increased nutrient and water uptake, environmental stress resistance (Sylvia and Williams, 1992), and pathogen resistance (Linderman, 2000). The AMF are found in association with roots of various fruit crops, including commercial strawberries (*Fragaria x ananassa* Duchense) and apple (*Malus x domestica* Borkh.)(Smith and Read, 1997).

Numerous studies have also shown the ability of AMF colonization to increase root, shoot, and fruit growth in both annual and perennial fruit crops. Yet, research is limited on the impact of organic ground covers on AMF symbiosis and its effects. Colonization by AMF has been found to be highest in soils with organic matter versus pure sand (Sylvia and Williams, 1992) and in strawberry and apple roots where peat and bark served as ground cover media compared to manure or sawdust (Derkowska et al., 2008). The objective of this research was to determine the influence of organic ground cover treatments on AMF colonization and symbiosis in terms of strawberry plant and apple tree growth. This project was part of a larger project on Best Management Practices for Organic Apple Orchards (NIFA-OREI 406).

MATERIALS AND METHODS

In January 2012, single strawberry plant propagation plugs (cv. Radiance) were transplanted into 20 cm × 18 cm plastic pots with chemically inert clay media. At planting, plants were given one of three treatments: 1) a control (NI) for inoculant treatment, 2) inoculated BioOrganics™ Endomycorrhizal Inoculant (BEI), or 3)

MegaGro® MycoBoost (MB), both applied at recommended label rates. After planting, plants were given one of the following four treatment combinations: A) a control (CK), B) city-generated green compost (GC), C) shredded paper (SP), or D) wood chips (WC) for a total of 12 treatments in the 3 × 4 factorial design. The experiment evaluated 10 replications of individual plant experimental units. Plants were arranged in a randomized design and grown in a greenhouse for 12 weeks after ground cover media application. Plants were watered by hand as necessary and each was provided with an application of 1.25 L (1:500 v/v fertilizer:water) of Scott's Miracle-Gro® Water Soluble All-Purpose Fertilizer at six weeks. Plants had access to full sun throughout the day. Ambient greenhouse temperatures were maintained between 20-25 °C for daytime hours and 25 °C for nighttime hours.

For a second study, in April 2012, rooted apple rootstocks (M. 26) were transplanted into 25 cm × 23 cm plastic pots with media of equal amounts of sand, vermiculite, and perlite by volume. As buds emerged, each plant was limited to one shoot by pinching to remove other laterals. Experimental treatments, experimental design, and duration were identical to that of the previously described strawberry experiment. Plants were watered by hand as necessary and each provided with an application of 1.75 L (1:500 v/v fertilizer:water) of Scott's Miracle-Gro® Water Soluble All-Purpose Fertilizer at 6 weeks. Plants had access to full sun throughout the day. Ambient greenhouse temperatures were maintained between 25 - 35°C for daytime hours and 25°C for nighttime hours.

Arbuscular Mycorrhizal Fungi Quantification. Root samples were cleared and stained according to a procedure by Sylvia (1994). The clearing agent was 1.8 M KOH and the bleaching agent was 30% wt/wt hydrogen peroxide acidified with a few drops of 5 M HCl. The stain was composed of 800 mL glycerine, 800 mL lactic acid, 800 mL distilled water, and 1.2 grams of trypan blue. Roots were stored in cold water after staining until processing. The grid-line-intersect method was used to determine percent AMF colonization with an average of 100 intersections per sample (Clapp et al., 1996).

Root and Vegetative Analysis. Roots were washed to clean them from soil particle matter. Roots were analyzed for length, average diameter, surface area, and volume using the WinRHIZO© scanner and software (Regent Instruments, Inc., Quebec, Canada). Root surface-area-to-volume ratio was calculated from these data. After measurements, half of the 10 replicates were randomly selected for AMF infection quantification. A 0.25-g sample of fresh roots was removed and stored in a tissue cassette in cold water until processing. The remaining roots were dried for 48 hours at 35-40 °C to measure root biomass.

Plants were harvested for growth assessments after 12 weeks of treatments. For both strawberry and apple plants, leaf area was measured with an area meter using a LiCor® Li-3000A portable area meter (LiCor Biosciences, Lincoln, Neb.). Total area was measured and average leaf area and specific leaf weight was calculated. Final shoot length of new shoot growth was measured for apple rootstocks. Apple and strawberry leaves as well as strawberry crowns were dried for 48 hours at 35-40 °C to measure vegetative biomass.

Statistical Analysis. The NI treatments and BEI treatments were selected to represent negative and positive AMF colonization, respectively. The treatment effects of inoculant × ground cover, inoculant, and ground cover were assessed. Statistical analysis was conducted using StatPlus (AnalystSoft Inc., Vancouver, B.C., Canada). Significance of differences were evaluated using two-way analysis of variance (ANOVA) and Fisher's least significant difference (LSD) where $P = 0.05$.

RESULTS AND DISCUSSION

Strawberry. In the strawberry study, the GC ground cover had a positive effect of increasing AMF root colonization in BEI inoculated treatments (Table 1). The BEI treatment resulted in overall larger colonization for each ground cover, though the CK and SP ground covers increased colonization in NI inoculated treatments.

The interaction between colonization treatment and ground cover treatment was only found to have significant differences in growth for total root length, average root diameter, and leaf area for strawberry (Table 1). Total root length was largest with ground cover treatments CK and GC in the NI inoculant treatment, with only GC in the NI inoculant treatment resulting in a mean different than that of GC in the BEI inoculant treatment. Average root diameter was significantly larger for CK, GC, and SP ground cover treatments in the BEI inoculant treatment than the NI inoculant treatment, with GC exhibiting the largest value. Leaf area was largest with the ground cover treatment GC in the NI inoculation treatment, which was significantly different compared to the BEI inoculation treatment.

Though past studies have demonstrated beneficial AMF symbiotic effects in terms of increased vegetative and root growth, this study showed minimal growth benefits due to AMF colonization. Variables that did not differ between inoculation treatment means for total ground cover treatments were leaf area (Table 1) and root dry weight, root surface area, root volume, aerial dry weight components, and total aerial dry weight (Table 2). Total root length and average root diameter varied significantly among ground cover treatments (Table 1), as did

root-surface-area-to-volume ratio (Table 2). The AMF appeared to increase average root diameter yet suppress total root length and root-surface-area-to-volume ratio. Root surface-area-to-volume ratio, which at larger values indicates increased root exposure to the environment for increased water and nutrient absorption (Bucher, 2004; Nijhoff, 1983), is typically increased in a host plant by AMF symbiosis (Bucher, 2004). This study contradicts this idea in strawberry plants.

Total ground cover treatments of NI + BEI resulted in significant differences among ground cover effects for plant growth (Tables 1 and 2). Average root diameter, root dry weight, root surface area, root volume, aerial dry weight components, leaf area and total aerial dry weight were largest for GC and insignificantly different between CK, SP, and WC. Root surface-area-to-volume-ratio was largest but not different between CK, SP, and WC, and was smallest for GC. Colonization of AMF was largest but not different between CK, GC, and SP, and was smallest for WC. Total root length was largest for CK and GC, followed by SP and WC.

Apple. In the apple study, the BEI inoculation treatment resulted in overall larger colonization for each ground cover than the NI inoculation treatment (Table 3). The GC ground cover treatment had a positive effect of increasing AMF root colonization in BEI inoculated treatments more than SP or WC. The CK treatment had the smallest colonization among ground covers inoculated with BEI, demonstrating the effectiveness of a ground cover to boost colonization in apple plants.

As found in the strawberry study, the interaction between colonization treatment and ground cover treatment in apple plants was only found to have significant differences in growth for total root length (Table 3). Total root length was largest with GC in the NI inoculant treatment which was significantly largest than the total root length mean with GC in the BEI inoculant treatment.

As with the strawberry study, in this study treatments resulted in minimal growth differences due to AMF colonization. Variables that did not differ among inoculation treatment means for total ground cover treatments were root dry weight, root diameter, root surface area, root volume, leaf area, shoot length, aerial dry weight components, and total aerial dry weight (Table 4). Total Root length (Table 3 and root surface-area-to-volume ratio (Table 4) varied among inoculation treatments with the varying ground covers. The AMF appeared to suppress total root length and root-surface-area-to-volume ratio in apple plants in addition to strawberry plants.

Total ground cover treatments of NI + BEI resulted in significant differences between ground cover effects on growth (Tables 3 and 4). Total root length, root dry weight, root diameter, root surface area, root volume, leaf area, shoot length, aerial dry weight components, and total aerial dry weight means were largest for GC and insignificantly different between CK, SP, and WC for total root length, root surface area, root volume, aerial dry weight components, and total aerial dry weight. The CK and WC treatments resulted in significantly smaller root dry weight and root diameter than either GC or SP. Shredded paper appeared to have a detrimental effect on both leaf area and shoot length compared to the other ground covers due to smaller means, though WC had a similar mean for leaf area. Root surface-area-to-volume-ratio was largest for CK and WC, followed by SP, and GC. Colonization of AMF was largest for GC, followed by SP and WC, and CK with the least value.

CONCLUSIONS

Though supplemental fertilizer was provided, ground cover treatments may have contributed disproportionately to plant and AMF nutrition. In green composting processes, it is common practice to grind, chip, or shred materials into smaller particles, which increases the surface area available for nutrient absorption (EPA, 2013). Plants may have been able to readily assimilate a proportion of the organic matter in GC. The WC, however, generally consists of large pieces of material that have less surface area available for nutrient absorption and contain lignin, cellulose and hemicellulose, which are difficult for microorganisms and plants to break down for nutrient release (Pan et al., 2005). The SP has a similar composition to WC and is also difficult to break down (Biermann, 1993). The GC provided more readily available nutrients compared to SP or WC, resulting in the greatest plant growth (shoot length, leaf area, aerial and root dry biomass, root volume) at similar rates in NI or BEI treatments. As previously mentioned, GC had a positive effect on AMF in inoculated plants by increasing colonization, indicating AMF need of available organic matter for establishment, which supports past data (Sylvia and Williams, 1992).

This study demonstrated the potential of GC as a ground cover for increasing AMF colonization compared to SP and WC, most likely due to increased available organic matter. Despite greater percent AMF infection in inoculated plants in the presence of GC, beneficial symbiotic effects of increased leaf area, shoot length for apple, root volume, root length, root surface area, or root volume-to-surface-area ratio were not demonstrated in this short-term study with strawberry and apple. In fact, GC application overrode any effect of AMF on plant growth. However, measurements were not conducted for increased water efficiency, pathogen suppression, or foliar P content. These potential beneficial effects would be

useful in organic fruit production, and could be affected by various ground cover media treatments. It would be valuable for future studies to examine these variables.

Another limitation of this study was duration. Future long-term greenhouse studies would be useful to determine the effect of ground cover media on AMF beneficial symbiosis for mature fruit crops. Long-term field studies would further provide real world analysis of the relationship of ground covers on AMF colonization and symbiosis.

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Table 1. Effect of inoculation treatment, ground cover treatment, and their interaction on arbuscular mycorrhizal fungi (AMF) root colonization, total root length, average root diameter, and leaf area of strawberry plants.

Treatment		AMF Colonization (%)	Total Root Length (cm)	Average Root Diameter (cm)	Leaf Area (cm^2)
Inoculant	**Ground Cover**				
Control	Control	24.93 ± 2.00 a‡	3284.00 ± 668.49 a	0.44 ± 0.08 ns	122.11 ± 38.11 b
	Green Compost	13.01 ± 3.15 b	3534.63 ± 498.65 a*	0.51 ± 0.08 ns	215.60 ± 30.62 a*
	Shredded Paper	21.97 ± 3.67 a	2669.91 ± 478.35 b	0.46 ± 0.06 ns	90.55 ± 44.77 b
	Wood Chips	11.22 ± 3.42 b	2477.59 ± 829.02 b	0.50 ± 0.09 ns	114.30 ± 76.56 b
	Total	17.78 ± 6.61 B§	2991.53 ± 750.82 A	0.48 ± 0.08 B	135.64 ± 68.49 NS
BEI†	Control	35.77 ± 3.28 b*	2619.90 ± 332.38 ns	0.54 ± 0.08 bc*	122.18 ± 28.95 ns
	Green Compost	51.15 ± 3.24 a*	2690.37 ± 455.00 ns	0.66 ± 0.13 a*	131.38 ± 93.11 ns
	Shredded Paper	41.36 ± 3.62 b*	2684.37 ± 373.30 ns	0.55 ± 0.08 b*	112.45 ± 27.05 ns
	Wood Chips	40.36 ± 2.95 b*	2505.57 ± 416.13 ns	0.49 ± 0.07 c	108.65 ± 40.09 ns
	Total	42.16 ± 6.49 A	2625.05 ± 388.65 B	0.56 ± 0.11 A	118.67 ± 53.05 NS
Control + BEI	Control	30.35 ± 6.26 α¶	2951.95 ± 616.50 αβ	0.49 ± 0.09 β	122.14 ± 32.94 β
	Green Compost	32.08 ± 20.33 α	3112.50 ± 635.15 α	0.59 ± 0.13 α	173.49 ± 80.11 α
	Shredded Paper	31.67 ± 10.78 α	2677.14 ± 417.67 βγ	0.51 ± 0.08 β	101.50 ± 37.71 β
	Wood Chips	25.79 ± 15.65 β	2491.58 ± 638.58 γ	0.50 ± 0.08 β	111.48 ± 59.55 β

† BioOrganics Endomycorrhizal Inoculant.

‡ Lowercase letters represent differences between ground cover treatments within an inoculant treatment where means labeled with the same letter are not significantly different according to two-way analysis of variance (ANOVA) and Fisher's least significant difference (LSD) ($\alpha < 0.05$, $n = 10$). No statistical significance is noted by ns.

§ Capital letters represent differences between inoculant treatments where means labeled with the same letter are not significantly different according to two-way ANOVA and Fisher's LSD ($\alpha < 0.05$, $n = 40$). No statistical significance is noted by NS.

¶ Lowercase Greek letters (greatest to least mean: α, β, γ) represent differences between ground cover treatments across both inoculant treatments where means labeled with the same letter are not significantly different according to two-way ANOVA and Fisher's LSD ($\alpha < 0.05$, $n = 20$).

* Represents statistically significant differences between the same ground cover treatments in both inoculation treatments according to two-way ANOVA and Fisher's LSD ($\alpha < 0.05$, $n = 10$). The largest mean is noted.

Table 2. Effect of ground cover treatment and inoculation treatment on (a) root dry weight, root surface area, root volume, root surface-area-to-volume ratio, and (b) aerial dry weight components and total aerial dry weight of strawberry plants.[†]

a.

Treatment		Root Dry Weight (g)	Root Surface Area (cm^2)	Root Volume (cm^3)	Root Surface-Area-to-Volume Ratio (cm^{-1})
Inoculant	**Ground Cover**				
Control	Total	0.81 ± 0.36 NS[§]	455.91 ± 151.88 NS	5.69 ± 2.71 NS	85.96 ± 14.78 A
BEI[‡]	Total	0.91 ± 0.39 NS	464.33 ± 121.75 NS	6.77 ± 3.05 NS	73.89 ± 13.29 B
Control + BEI	Control	0.78 ± 0.32 b[¶]	449.37 ± 101.75 b	5.64 ± 2.09 b	84.59 ± 16.82 a
	Green Compost	1.13 ± 0.41 a	563.66 ± 125.13 a	8.49 ± 3.30 a	71.27 ± 15.26 b
	Shredded Paper	0.83 ± 0.33 b	428.71 ± 110.27 b	5.59 ± 2.24 b	81.09 ± 12.77 a
	Wood Chips	0.69 ± 0.31 b	398.74 ± 152.55 b	5.20 ± 2.78 b	82.75 ± 13.18 a

b.

Treatment		Crown Dry Weight (g)	Petiole Dry Weight (g)	Leaf Dry Weight (g)	Total Aerial Dry Weight (g)
Inoculant	**Ground Cover**				
Control	Total	4.00 ± 1635 NS	0.57 ± 0.43 NS	3.77 ± 2.03 NS	8.35 ± 3.81 NS
BEI	Total	4.15 ± 1.35 NS	0.58 ± 0.52 NS	3.78 ± 2.25 NS	8.51 ± 3.88 NS
Control + BEI	Control	3.61 ± 1.00 b	0.37 ± 0.21 b	3.27 ± 0.88 b	7.25 ± 1.87 b
	Green Compost	5.23 ± 1.69 a	1.19 ± 0.50 a	6.16 ± 2.45 a	12.59 ± 4.18 a
	Shredded Paper	3.78 ± 1.46 b	0.34 ± 0.24 b	2.73 ± 1.03 b	6.84 ± 2.60 b
	Wood Chips	3.67 ± 1.14 b	0.41 ± 0.23 b	2.94 ± 1.70 b	7.03 ± 2.92 b

[†] The differences in interactions between inoculation and ground cover treatments were not found to be statistically significant according to two-way analysis of variance (ANOVA) and Fisher's least significant difference (LSD) ($\alpha < 0.05$, n = 10) and these means are therefore not listed.

[‡] BioOrganics Endomycorrhizal Inoculant.

[§] Capital letters represent differences between inoculant treatments where means labeled with the same letter are not significantly different according to two-way ANOVA and Fisher's LSD ($\alpha < 0.05$, n = 40). No statistical significance is noted by NS.

[¶] Lowercase letters represent differences between ground cover treatments across both inoculant treatments where means labeled with the same letter are not significantly different according to two-way ANOVA and Fisher's LSD ($\alpha < 0.05$, n = 20).

Table 3. Effect of inoculation treatment, ground cover treatment, and their interaction on percent (%) arbuscular mycorrhizal fungi root colonization and total root length of apple plants.

Treatment		AMF Colonization	Total Root Length
Inoculant	Ground Cover	(%)	(cm)
Control	Control	4.34 ± 0.90 ns‡	1297.23 ± 469.32 bc*
	Green Compost	4.91 ± 2.00 ns	2169.94 ± 404.14 a*
	Shredded Paper	4.03 ± 1.20 ns	1030.67 ± 313.07 cd
	Wood Chips	4.65 ± 0.70 ns	797.26 ± 348.30 d
	Total	4.48 ± 1.24 B§	1323.78 ± 644.99 A
BEI†	Control	33.99 ± 4.74 c*	879.90 ± 388.82 b
	Green Compost	53.37 ± 2.29 a*	1508.81 ± 585.76 a
	Shredded Paper	41.17 ± 4.32 b*	1059.04 ± 365.02 ab
	Wood Chips	44.94 ± 3.18 b*	993.09 ± 353.32 b
	Total	43.37 ± 7.95 A	1110.21 ± 481.82 B
Control + BEI	Control	19.17 ± 15.96 γ¶	1088.57 ± 470.93 β
	Green Compost	29.14 ± 25.62 α	1839.37 ± 595.75 α
	Shredded Paper	22.60 ± 19.80 β	1044.85 ± 331.29 β
	Wood Chips	24.80 ± 21.34 β	895.18 ± 355.93 β

† BioOrganics Endomycorrhizal Inoculant.

‡ Lower case letters represent differences between ground cover treatments within an inoculant treatment where means labeled with the same letter are not significantly different according to two-way analysis of variance (ANOVA) and Fisher's least significant difference (LSD) ($\alpha < 0.05$, $n = 10$). No statistical significance is noted by ns.

§ Capital letters represent differences between inoculant treatments where means labeled with the same letter are not significantly different according to two-way ANOVA and Fisher's LSD ($\alpha < 0.05$, $n = 40$).

¶ Lower case Greek letters (greatest to least mean: α, β, γ) represent differences between ground cover treatments across both inoculant treatments where means labeled with the same letter are not significantly different according to two-way ANOVA and Fisher's LSD ($\alpha < 0.05$, $n = 20$).

* Represents statistically significant differences between the same ground cover treatments in both inoculation treatments according to two-way ANOVA and Fisher's LSD ($\alpha < 0.05$, $n = 10$). The largest mean is noted.

Table 4. Effect of ground cover treatment and inoculation treatment on (a) root dry weight, average root diameter, root surface area, root volume, root surface-area-to-volume ratio, and (b) leaf area, shoot length, aerial dry weight components, and total aerial dry weight of apple plants.[†]

a.

Treatment		Root Dry Weight (g)	Root Diameter (cm)	Root Surface Area (cm^2)	Root Volume (cm^3)	Root Surface-Area-to-Volume Ratio (cm^{-1})
Inoculant	**Ground Cover**					
Control	Total	1.01 ± 0.85 NS[§]	0.67 ± 0.22 NS	302.50 ± 207.70 NS	6.05 ± 6.31 NS	63.99 ± 16.11 A
BEI[‡]	Total	1.13 ± 1.02 NS	0.75 ± 0.33 NS	297.95 ± 220.03 NS	6.66 ± 6.94 NS	54.33 ± 20.21 B
Control + BEI	Control	0.52 ± 0.36 c[¶]	0.55 ± 0.18 c	197.33 ± 99.09 b	2.99 ± 2.01 b	69.00 ± 21.03 a
	Green Compost	2.24 ± 0.88 a	0.97 ± 0.38 a	576.86 ± 204.38 a	14.50 ± 7.65 a	41.15 ± 13.62 c
	Shredded Paper	0.96 ± 0.73 b	0.74 ± 0.19 b	253.67 ± 134.50 b	5.21 ± 4.29 b	57.33 ± 13.33 b
	Wood Chips	0.56 ± 0.37 c	0.59 ± 0.09 bc	173.05 ± 85.19 b	2.72 ± 1.64 b	69.15 ± 10.61 a

b.

Treatment		Leaf Area (cm^2)	Shoot Length (cm)	Shoot Dry Weight (g)	Leaf Dry Weight (g)	Total Aerial Dry Weight (g)
Inoculant	**Ground Cover**					
Control	Total	723.93 ± 743.28 NS	40.61 ± 23.79 NS	3.70 ± 4.14 NS	5.43 ± 5.33 NS	9.13 ± 9.26 NS
BEI	Total	723.17 ± 741.54 NS	38.84 ± 24.16 NS	3.72 ± 4.77 NS	5.97 ± 6.55 NS	9.69 ± 11.28 NS
Control + BEI	Control	524.53 ± 237.95 b	34.28 ± 11.60 b	1.93 ± 0.96 b	3.87 ± 1.71 b	5.79 ± 2.64 b
	Green Compost	1708.98 ± 871.98 a	72.30 ± 21.60 a	10.35 ± 4.24 a	13.83 ± 6.82 a	24.18 ± 10.70 a
	Shredded Paper	218.74 ± 97.92 c	20.78 ± 7.17 c	1.00 ± 0.58 b	1.79 ± 0.73 b	2.79 ± 1.21 b
	Wood Chips	441.95 ± 143. 45 bc	31.55 ± 10.70 b	1.58 ± 0.81 b	3.29 ± 1.13 b	4.87 ± 1.86 b

[†] The differences in interactions between inoculation and ground cover treatments were not found to be statistically significant according to two-way analysis of variance (ANOVA) and Fisher's least significant difference (LSD) ($\alpha < 0.05$, $n = 10$) and these means are therefore not listed.

[‡] BioOrganics Endomycorrhizal Inoculant.

[§] Capitol letters represent differences between inoculant treatments where means labeled with the same letter are not significantly different according to two-way ANOVA and Fisher's LSD ($\alpha < 0.05$, $n = 40$). No statistical significance is noted by NS.

[¶] Lower case letters represent differences between ground cover treatments across both inoculant treatments where means labeled with the same letter are not significantly different according to two-way ANOVA and Fisher's LSD ($\alpha < 0.05$, $n = 20$).