Do commercial mycorrhizae inoculants improve raspberry growth?

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The Fact Is…

Raspberry is important in WA, however…

- Synthetic fertilizers and soil fumigation

Inadvertently reduce beneficial soil biota

(Geisseler and Scow, 2014; Mazzola et al., 2015)

- Buildup of soil-borne pathogens (root rot and root lesion nematode)

Reduce raspberry health

(Rudolph and DeVetter, 2015)

Photo by J.E. Weiland

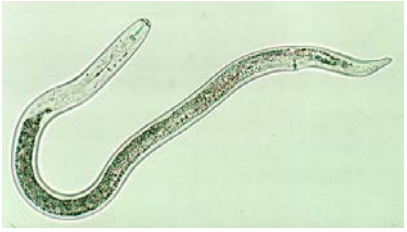
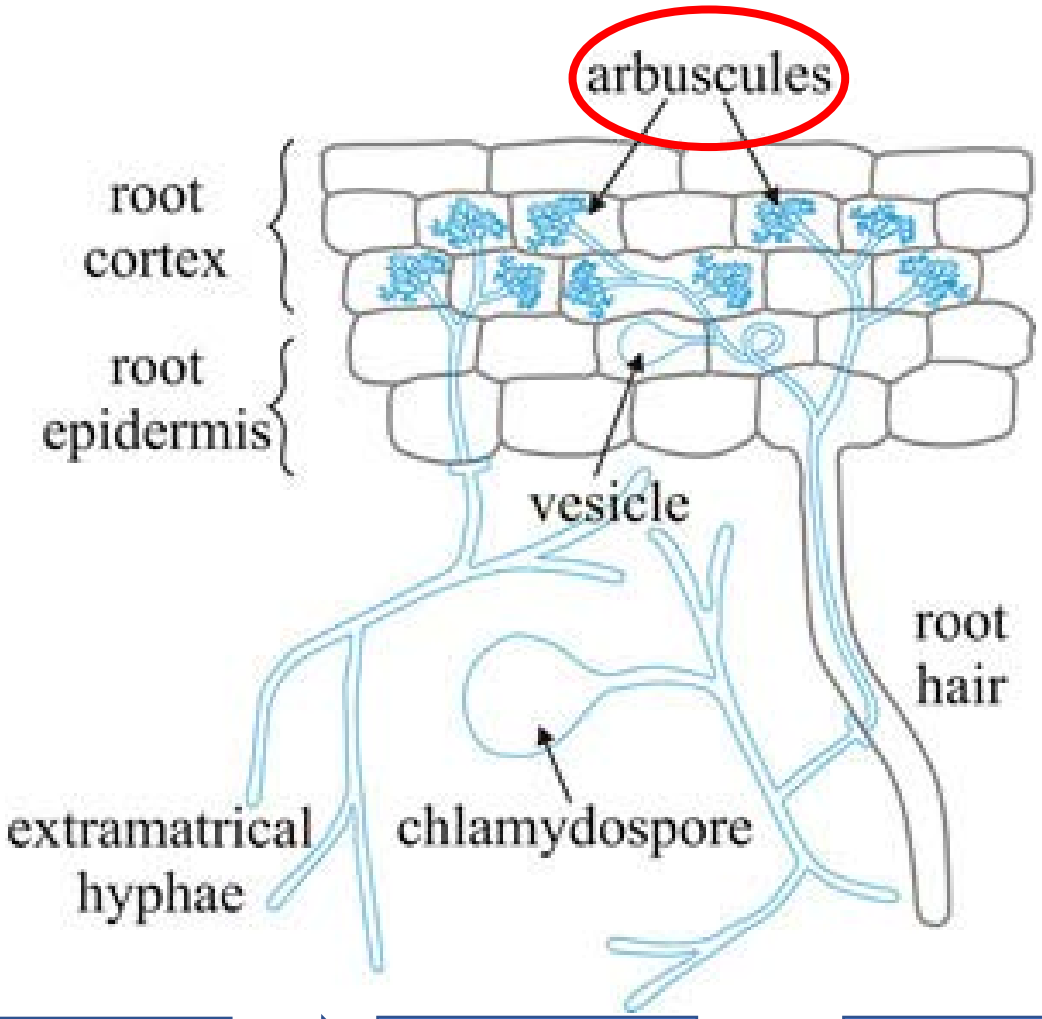


Photo from Department of Agriculture and Food of Western Australia

Reduce raspberry productivity

Arbuscular Mycorrhizae (AM) Fungi



- Form symbiosis with host plants
- Provide nutrients in exchange of photosynthetic products
- Major function: increase plant uptake of nutrients

Hyphae → Root hair → Root cortex → Arbuscular formation

Source/image: Moore et al., 2011

We Find That…

JULY 29, 2019 BY LANDSCAPE-WATER-CONSERVATION

Benefits of Mycorrhizae

Potential Benefits of Mycorrhizae:

- Enhanced water and nutrient uptake
- Reduction of irrigation requirements
- Reduction need for fertilizer
- Increased drought resistance
- Increased pathogen resistance
- Increased plant health and stress tolerance
- Higher transplanting success

Source/image: News from landscape water conservation on 07/29/2019

COMMUNICATIONS BIOLOGY

ARTICLE

https://doi.org/10.1038/s42003-019-0481-8 OPEN

Synergies between mycorrhizal fungi and soil microbial communities increase plant nitrogen acquisition

Rachel Hestrin[1], Edith C. Hammer[2], Carsten W. Mueller[3] & Johannes Lehmann[1,4,5]

Source: Hestrin et al., 2019

Research Article

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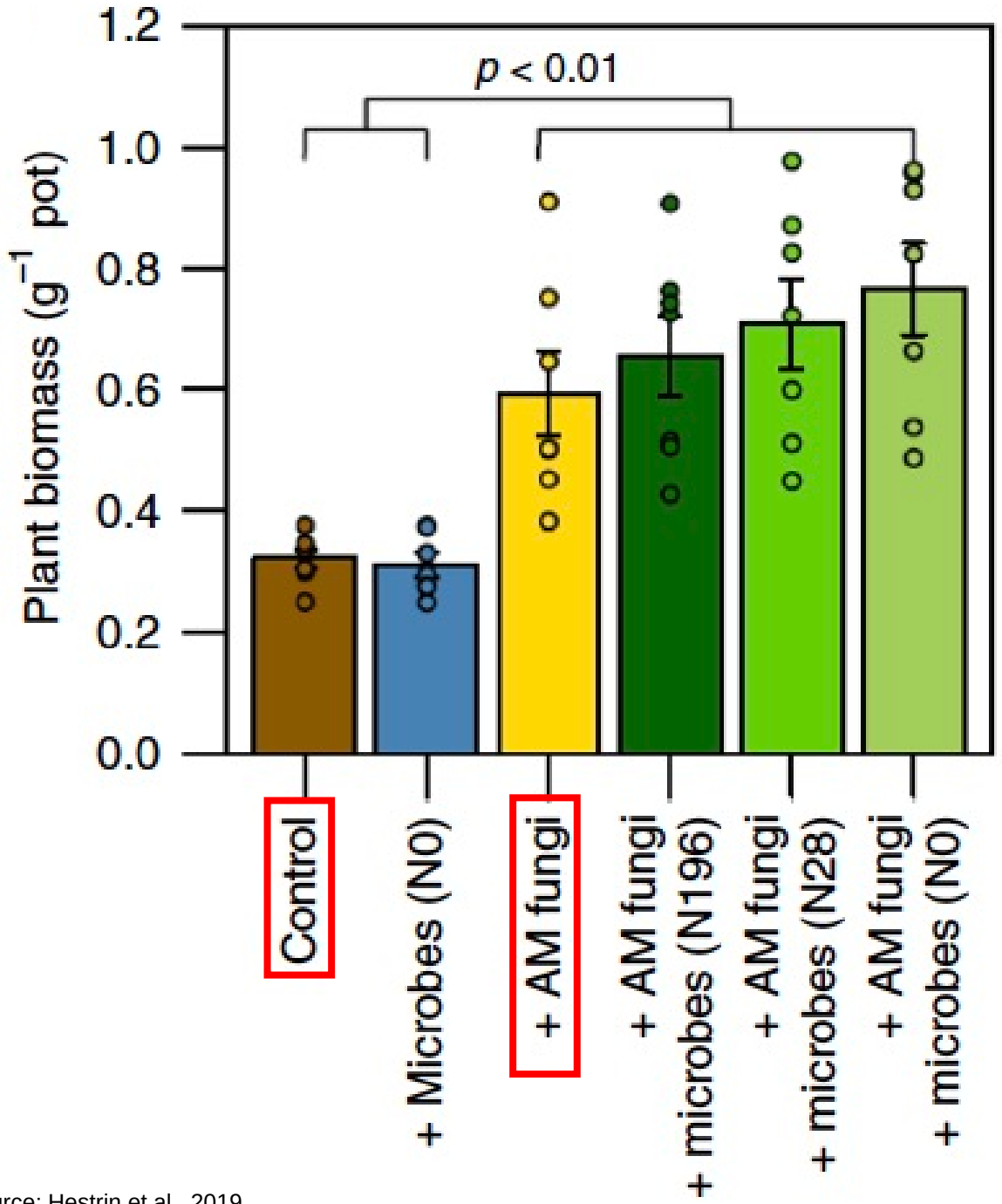
(wileyonlinelibrary.com) DOI 10.1002/jsfa.9316

Effect of fertilization and arbuscular mycorrhizal fungal inoculation on antioxidant profiles and activities in *Fragaria ananassa* fruit

José Parada,[a] Tamara Valenzuela,[a] Francisca Gómez,[a] Gonzalo Tereucán,[a] Susana García,[a,b] Pablo Cornejo,[a,b] Peter Winterhalter[c] and Antonieta Ruiz[a,b*]

Source/image: Parada et al., 2018



ARTICLE

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Synergies between mycorrhizal fungi and soil microbial communities increase plant nitrogen acquisition

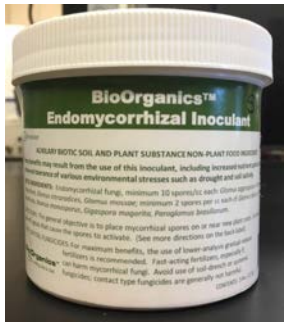
Rachel Hestrin[1], Edith C. Hammer[2], Carsten W. Mueller[3] & Johannes Lehmann[1,4,5]

Plant biomass response

- Plants colonized with AM fungi are associated with significantly higher biomass than control plants

Source: Hestrin et al., 2019

Commercial mycorrhizae big sale!!!



**mmmm…
Let me think**

Source/image: The Simpsons; Cartoon Raspberry

1 Background

- Mycorrhizae fungi
  - ✓Mobilize and transfer nutrients to plants
  - ✓Mitigate biotic and abiotic stress
  - ✓Less susceptible to diseases
- Organic-derived fertilizer source
  - ✓Provide nutrients in long run with slow releasing rate
  - ✓Increase soil quality
  - ✓Reduce pollution

Parada et al., 2018

Altamimi et al., 2013

Nicholson et al., 2015

Douds et al., 2017

Potential benefits of these two factors have not been characterized in raspberry !!!

Source/image: Fruit and vegetable pictures

2 Objective

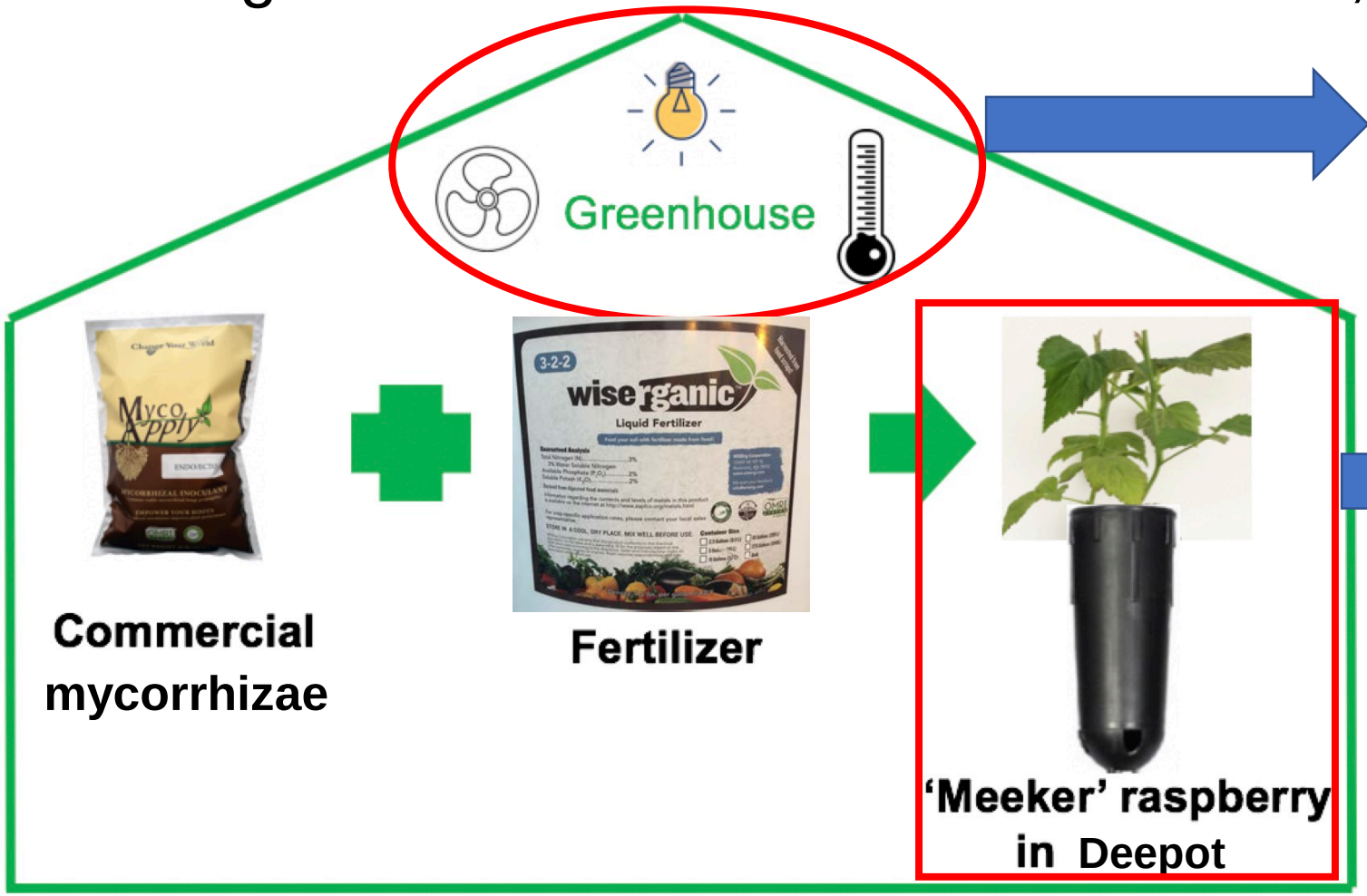
Objective: Evaluate combined effects of different fertilizer sources and mycorrhizae fungal inoculants in red raspberry

Experiment: Greenhouse experiment evaluating different commercial mycorrhizae inoculants and fertilizer sources

3 Experimental Approaches

WASHINGTON STATE UNIVERSITY

A greenhouse experiment was established at the Northwestern Washington Research and Extension Center, WSU, in June 2019

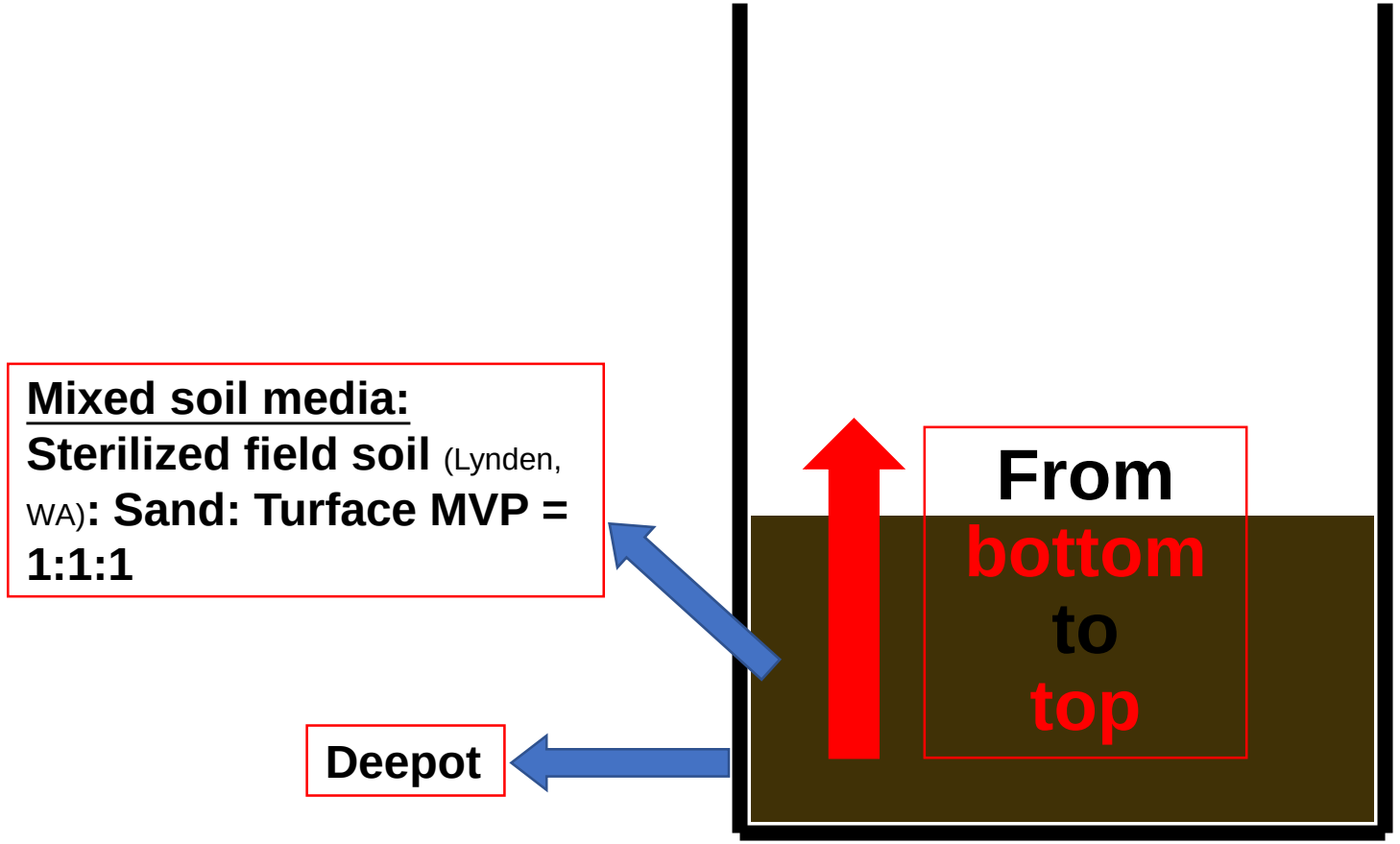


Light: 12 hr day/night cycle
Temperature: 16 °C (60.8 °F)
Temperature and Humidity were recorded at 15 min intervals with HOBO Data Logger (Onset, Bourne, MA).

'Sandwich' method

Sandwich

Schematic figure of ‘sandwich’ method



Sandwich

Schematic figure of ‘sandwich’ method

Fertilizer treatments:

1. Organic fertilizer: WISErganic (3-0.9-1.7)

2. Synthetic fertilizer: Urea(46)**+phosphate** (19.6)**+potash**(49.8)

3. No fertilizer control

Note: Organic and synthetic fertilizer treatments have consistent N, P, K

Tissue culture ‘Meeker’ raspberry

Raspberry roots

Mycorrhizal inoculation treatments:

1. **Bio-Organics** (Bio-Organics LLC, New Hope, PA)

2. **Endo** (Mycorrhizal Applications, Grants Pass, OR)

3. **MYKOS** (Xtreme Gardening, Gilroy, CA)

4. **Raspberry field community** (Lynden, WA)

5. **Non-inoculated control**

Mixed soil media:

Sterilized field soil (Lynden, WA)**: Sand: Turface MVP = 1:1:1**

Deepot

From bottom to top

Experimental Design

- Randomized complete block design (RCBD)
- 8 replications (blocks)
- 5 mycorrhizae × 3 fertilizer =15 treatment combinations

Data Collection

Jun-Oct, 2019

- **Plant growth.**
  Plant height
  Chlorophyll content
  Shoot and root biomass

- **Plant and soil nutrients.**
  Macro- and micro- nutrient concentrations of plant shoots

- **Mycorrhizae fungal colonization.**

4 Results

June

August

October

Procedures of Observing and Calculating Fungal Colonization

WASHINGTON STATE UNIVERSITY

Raspberry roots

Clearing

(2.5 % KOH)

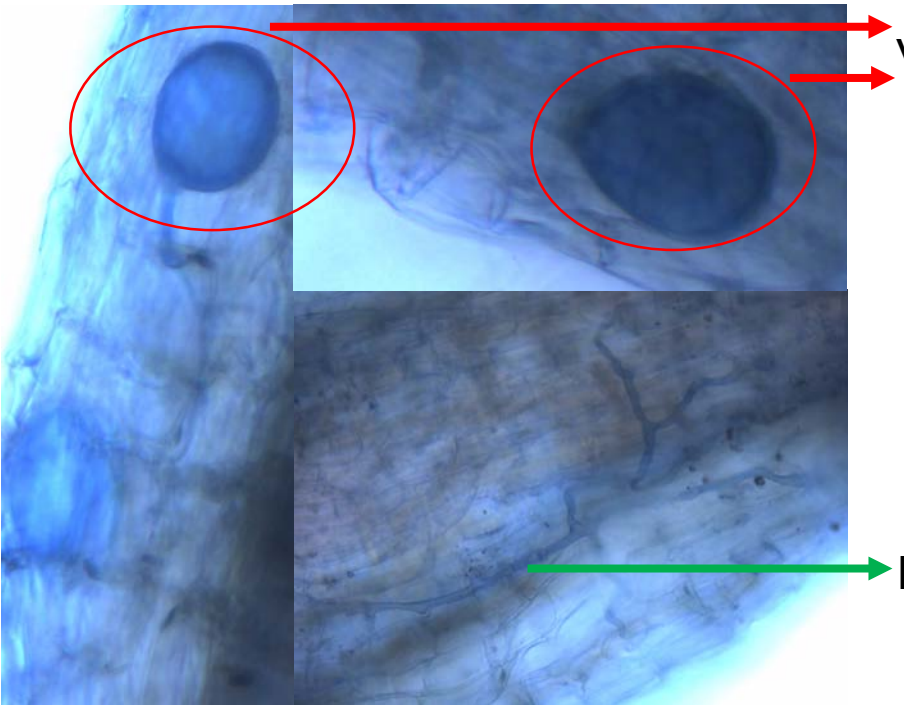
Staining (0.05% Trypan blue)

Root slide

Observation

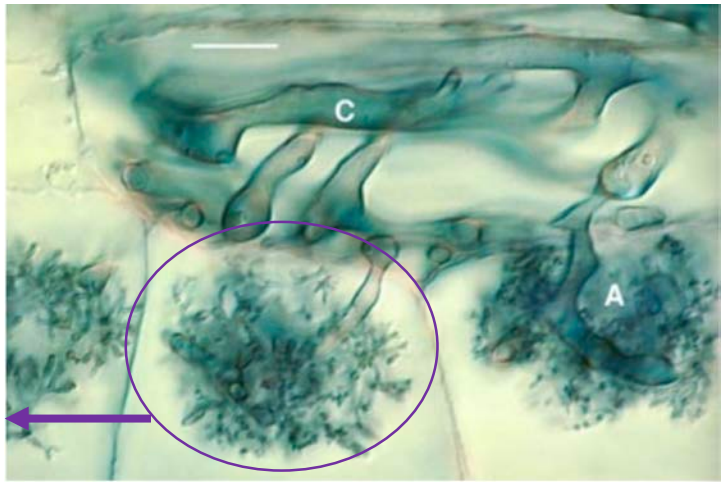
Counting

Microscope



Vesicles

Hyphae



Arbuscule

Brundrett 2008

Magnified intersections method

Mycorrhizae Colonization rate

Table 1. Mycorrhizae colonization rates of red raspberry roots

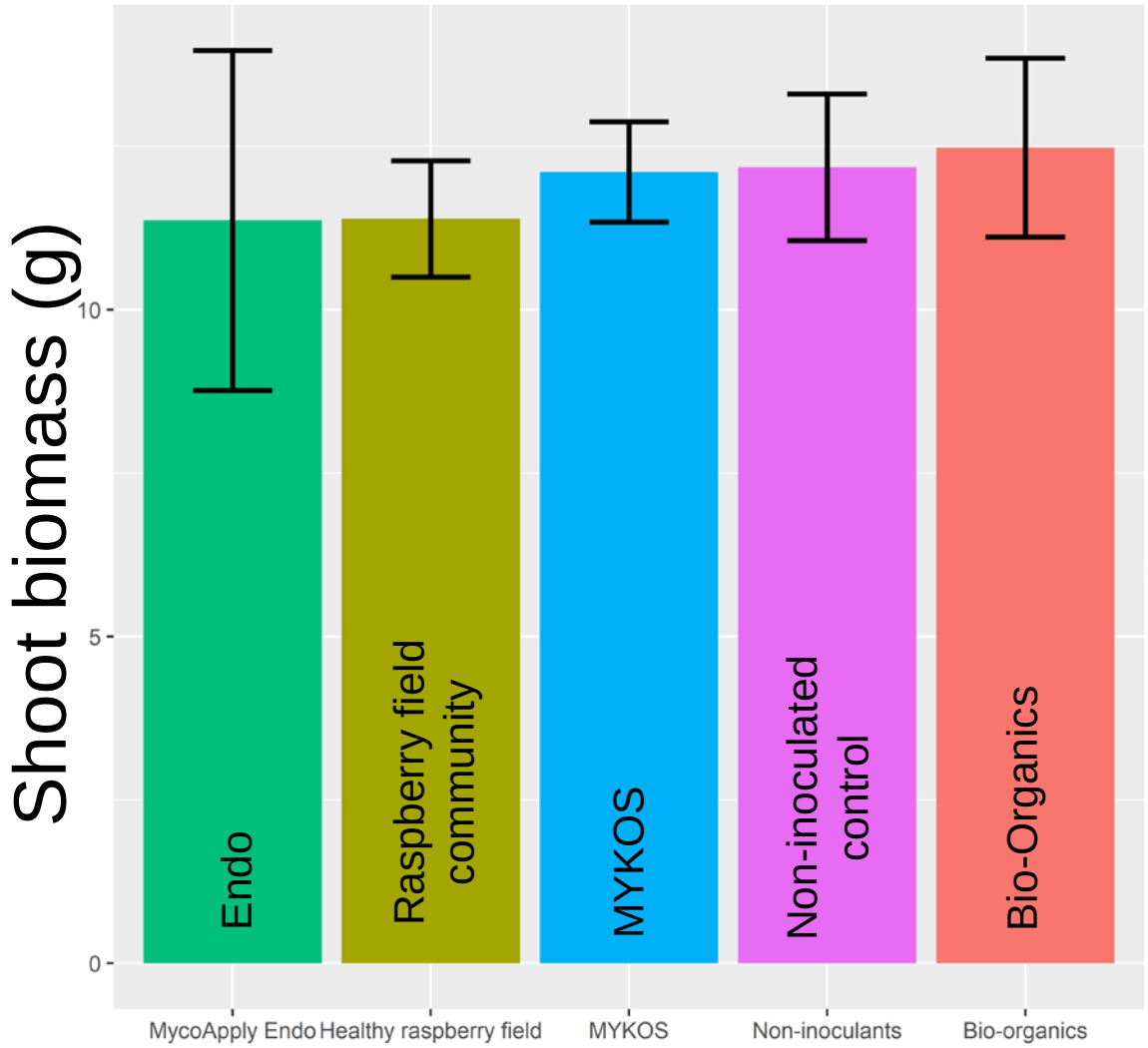
	Treatment combination	Colonization rate (%)[y]
WISErganic	Bio-Organics	17 ± 3 a[z]
	Endo	10 ± 1 b
	MYKOS	22 ± 2 a
	Raspberry field community	2 ± 1 c

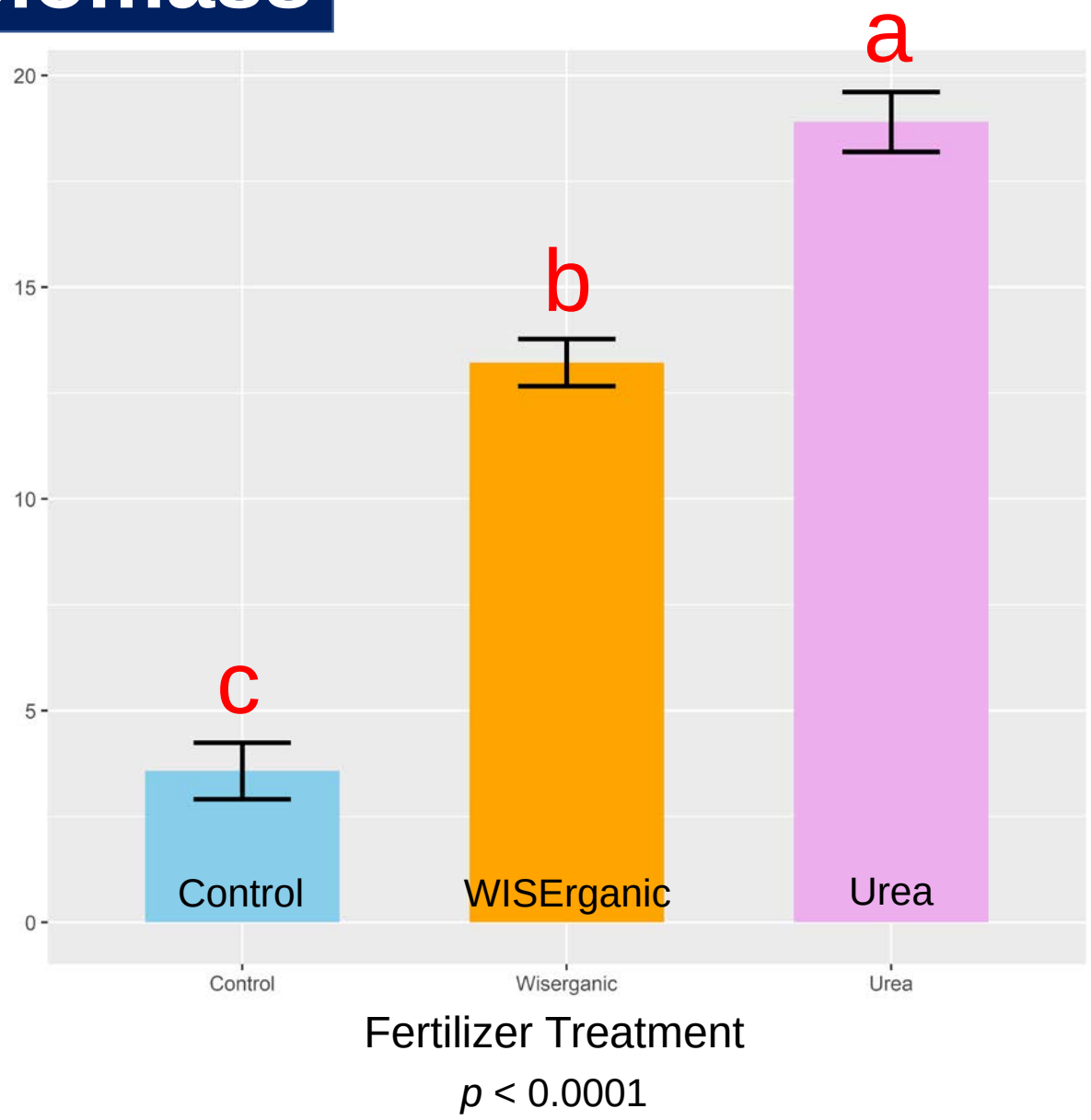
	Treatment combination	Colonization rate (%)
Urea	Bio-Organics	32 ± 4 a
	Endo	4 ± 1 b
	MYKOS	26 ± 2 a

[y]Only vesicles and hyphae are observed, no arbuscules are found

[z] Data displayed are means ± standard errors (SE) (sample size=3), different letters under the same fertilizer treatment represent significant difference ($p < 0.05$)

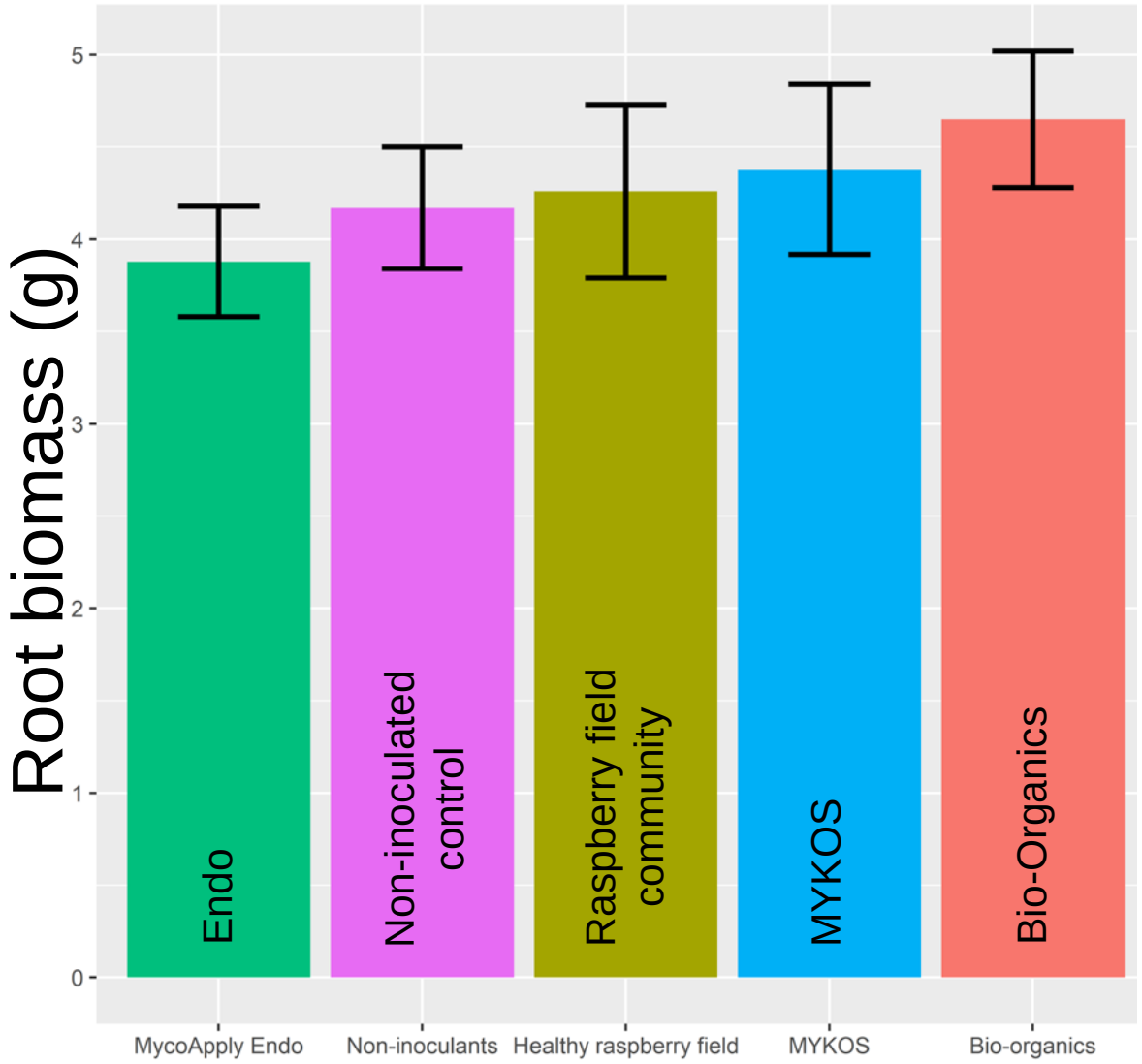
Shoot Biomass





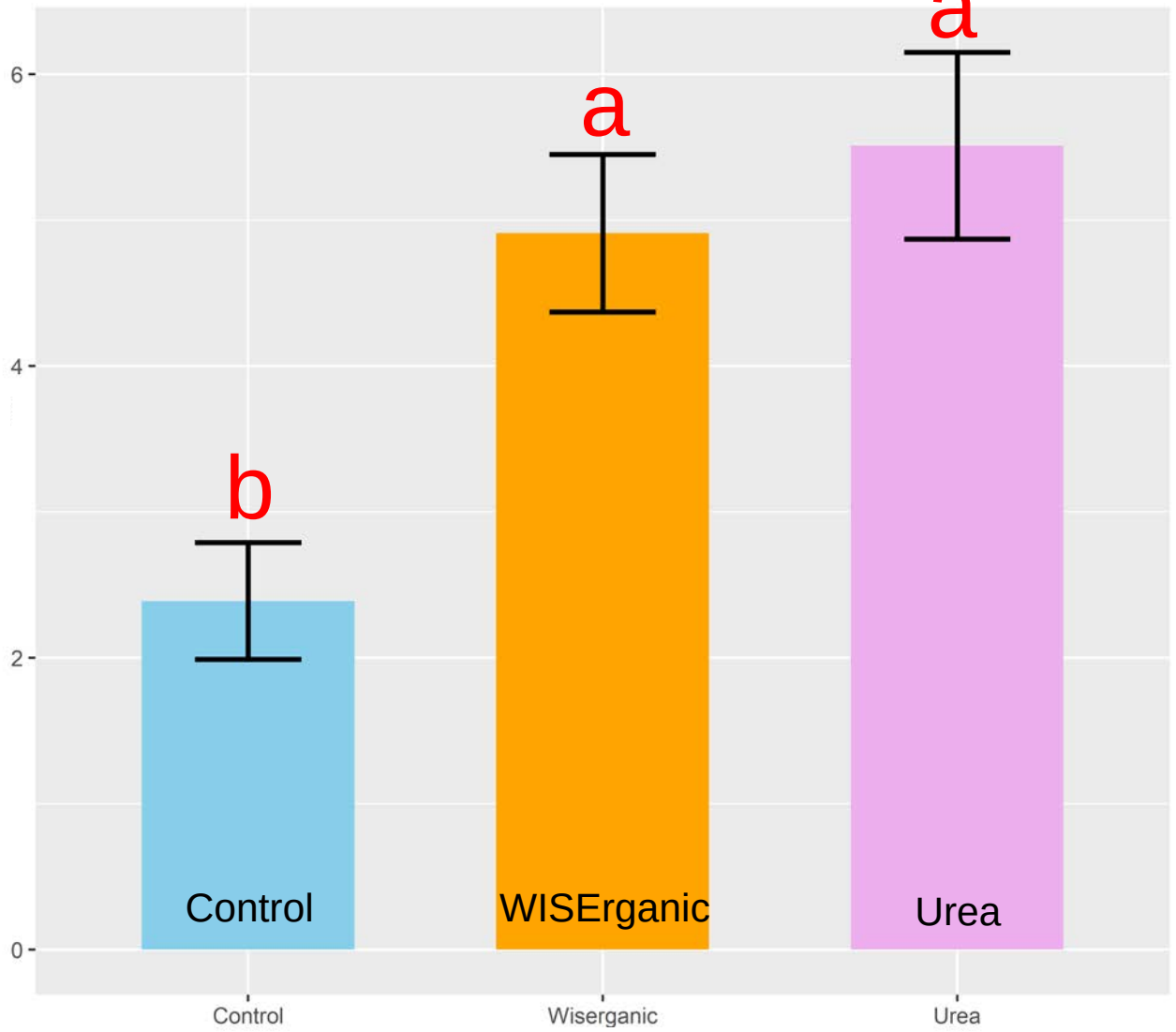
Different letters in the same graph represent significant difference ($p < 0.05$)

Root Biomass



Mycorrhizae Treatment

p = 0.2849



Fertilizer Treatment

p = 0.0013

Different letters in the same graph represent significant difference ($p < 0.05$)

5 Conclusions

- Plants formed more mycorrhizae with MYKOS and Bio-Organics than Endo

- Growth measurements were more impacted by fertilizer treatment than mycorrhizal inoculants

- Further research are needed to justify the role of mycorrhizae on raspberry growth and development

Acknowledgements

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Yixin Cai

WASHINGTON STATE UNIVERSITY

Thank you!

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For more information about raspberry, please visit

https://smallfruits.wsu.edu/raspberry/

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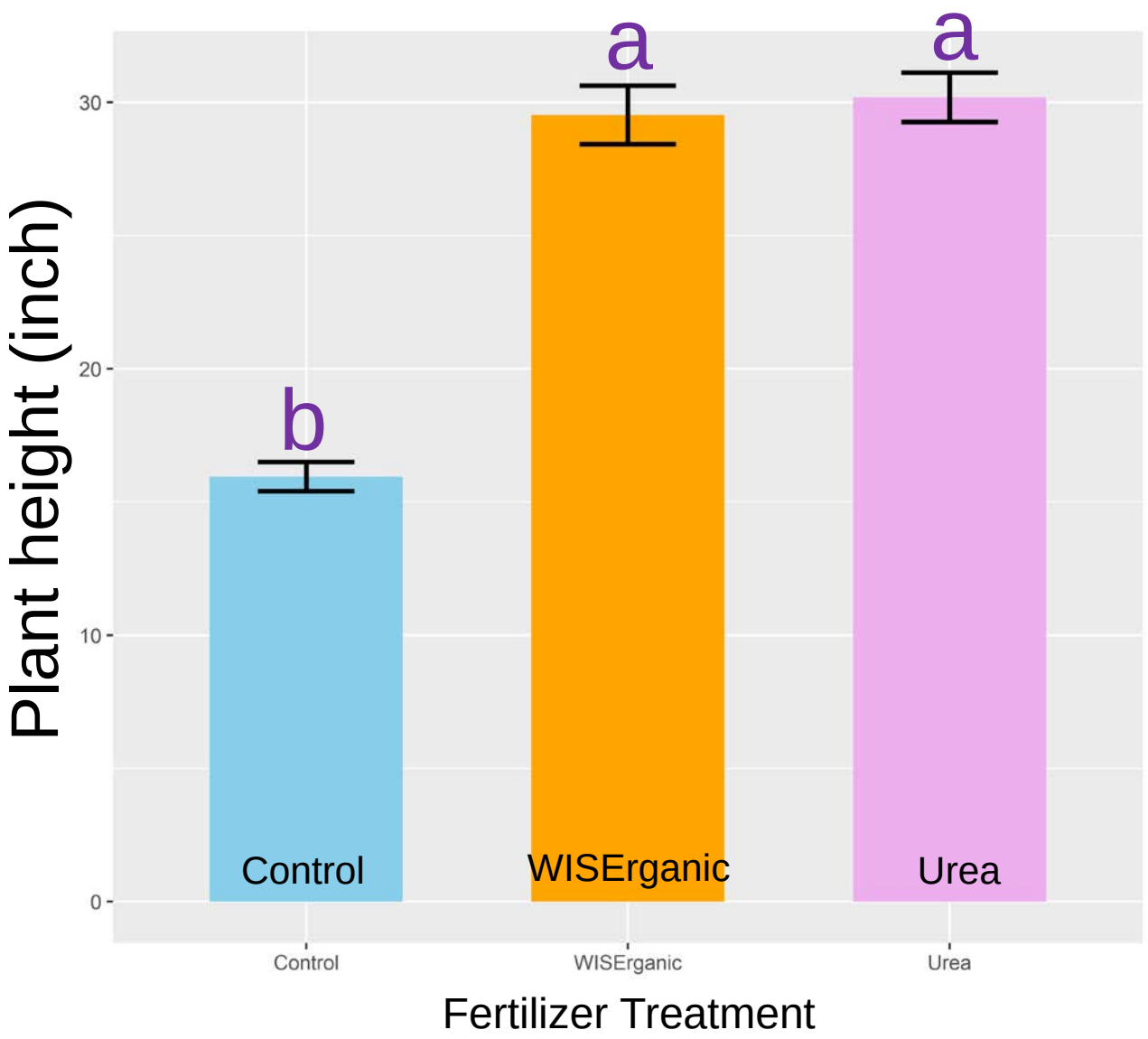
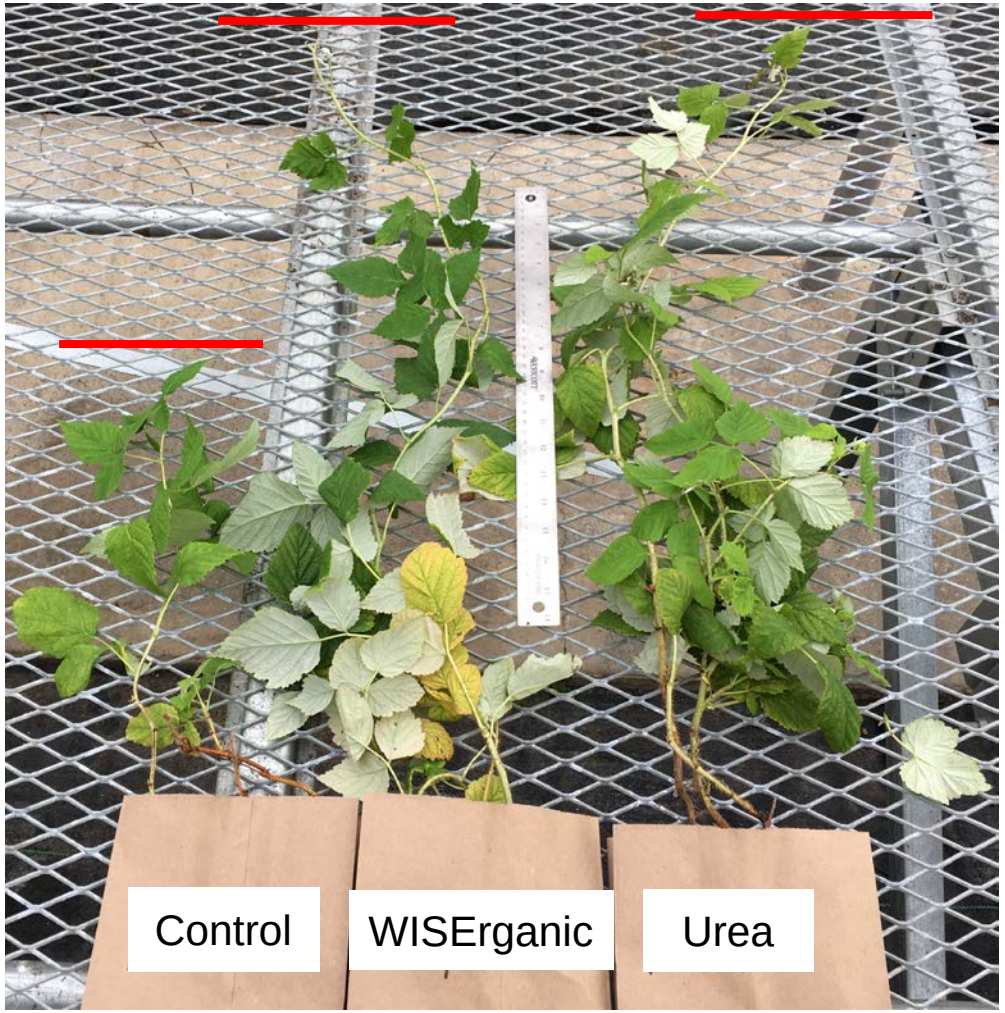
Plant Height by Treatment





Different letters represent significant difference ($p < 0.05$)

Mycorrhizae Colonization rate

Table 1. Mycorrhizae colonization rates of red raspberry roots

	Treatment	Vesicles[y] Colonization rate	Hyphae Colonization rate
WISErganic	Bio-Organics	0.09±0.01 a[z]	0.08±0.02 b
	Endo	0.05±0.01 b	0.05±0.01 c
	MYKOS	0.11±0.02 a	0.11±0.01 b
	Raspberry field community	0.01±0.00 c	0.01±0.00 d
Urea	Bio-Organics	0.14±0.03 a	0.18±0.03 a
	Endo	0.01±0.00 c	0.03±0.01 c
	MYKOS	0.11±0.02 a	0.15±0.03 a

[y]Only vesicle and hyphae are observed, no arbuscules are found

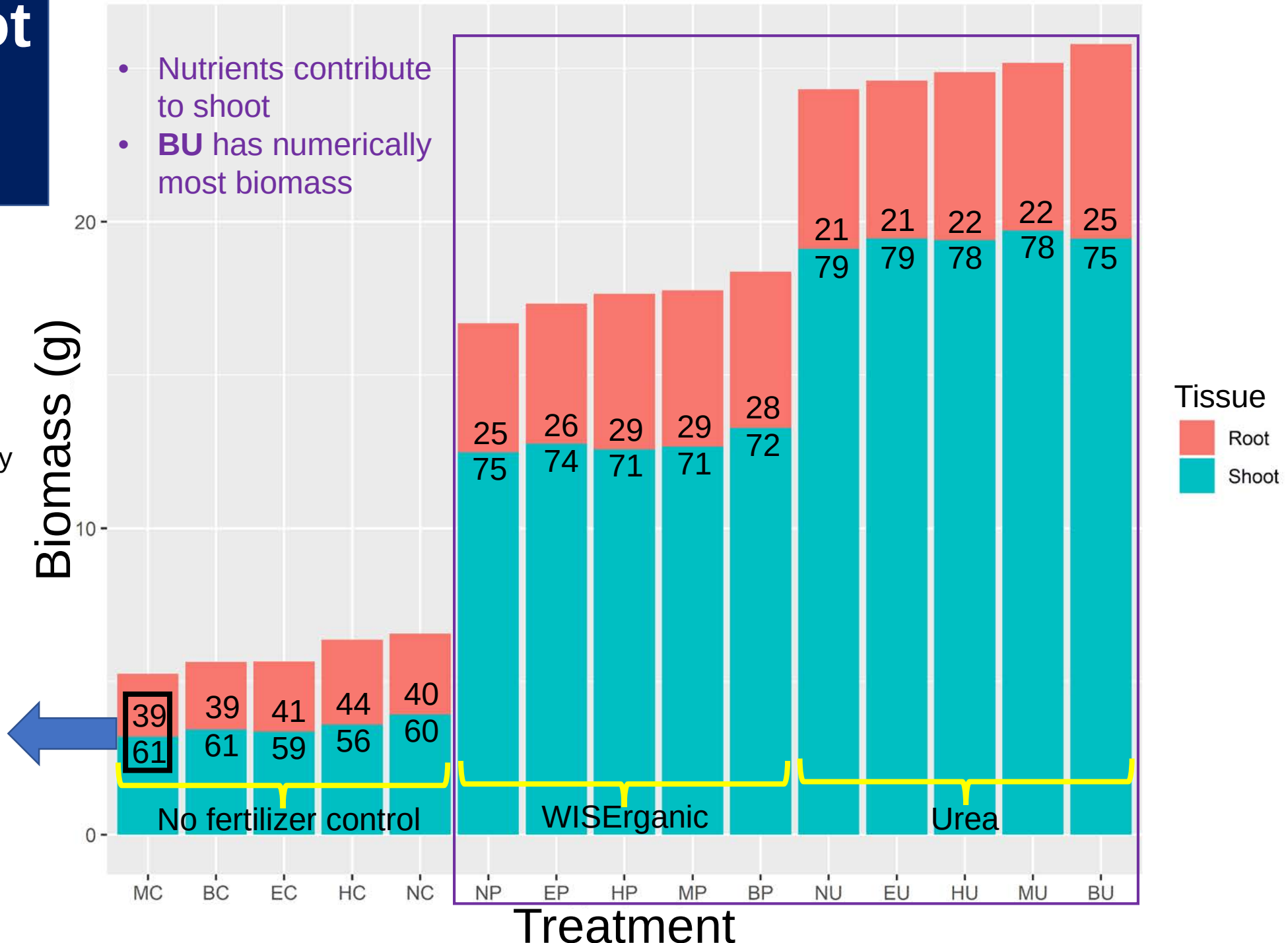
[z] Data displayed are means ± standard errors (SE) (sample size=3), different letters within the same column represent significant difference ($p < 0.05$)

Shoot & Root Biomass by Treatment

- Nutrients contribute to shoot
- **BU** has numerically most biomass

Treatment description:
Mycorrhizae
B: Bio-Organics
E: Endo
M: MYKOS
H: Raspberry field community
N: Non-inoculated control
Fertilizer
P: WISErganic
U: Urea
C: No fertilizer control

Number: Percentage of root biomass and shoot biomass, separately



Fertilizer Details

Time	Fertilizer sources		
	Wiserganic	Urea+phosphate+potash	No fertilizer control
Jul 10	5ml	Urea: 0.37g+Phosphate: 0.26g+Potash: 0.19g	27.39 mg Urea
Sept 10	5ml	Urea: 0.37g+Phosphate: 0.26g+potash: 0.19g	27.39 mg Urea

Organic fertilizer

Synthetic fertilizer

Control

	N/g	P/g	K/g
Jul 10	0.17	0.05	0.10
Sep 10	0.17	0.05	0.10

Consistent N, P, K

	N/mg	P/mg	K/mg
Jul 10	12.6	0	0
Sept 10	12.6	0	0

Let control plants survive

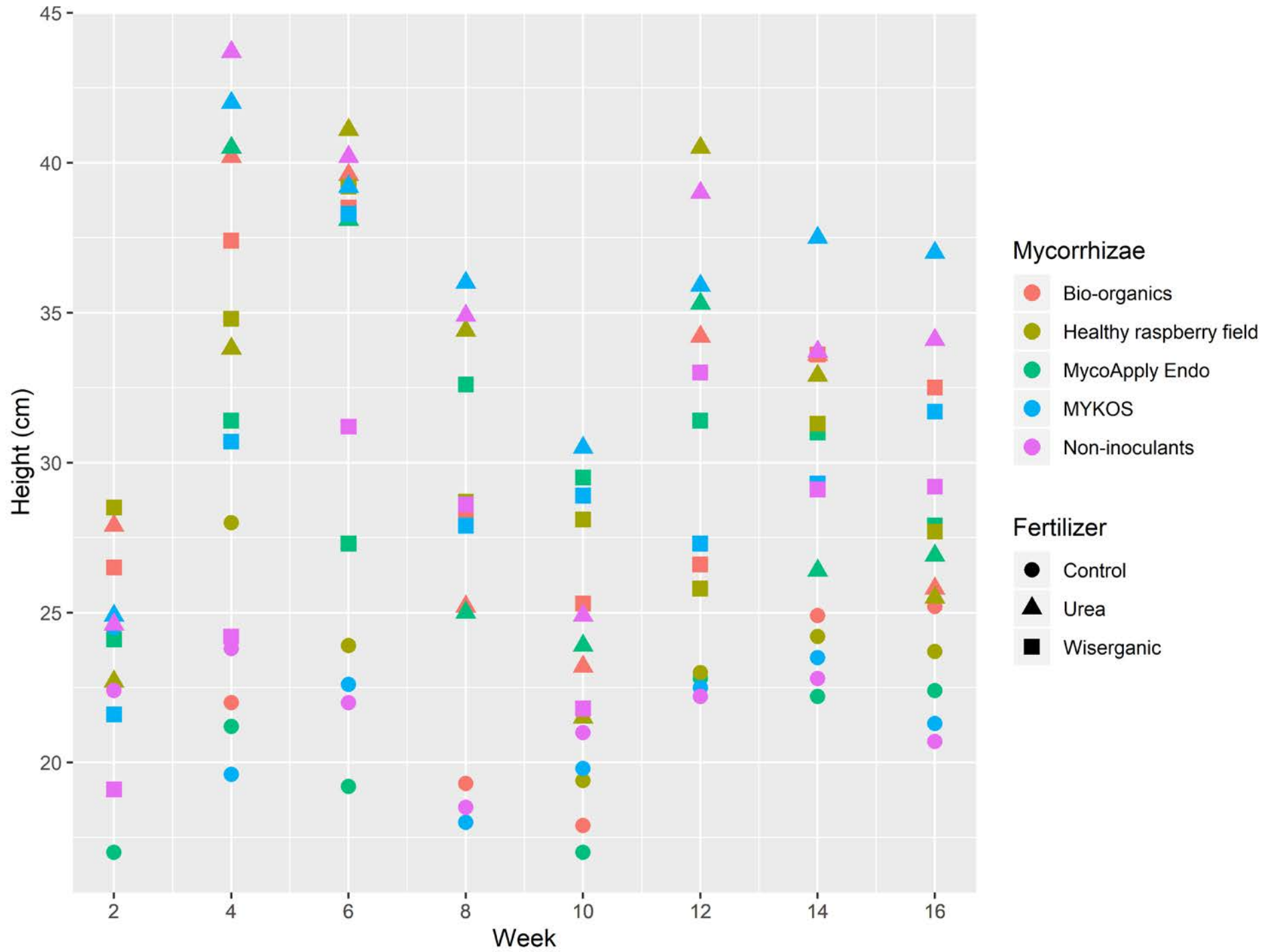

Height (cm)
45
40
35
30
25
20
2
4
6
8
10
12
14
16
Week
Mycorrhizae
Bio-organics
Healthy raspberry field
MycoApply Endo
MYKOS
Non-inoculants
Fertilizer
Control
Urea
Wiserganic

Table 4. Characteristics of field soil and mixed soil media

	Field soil	Mixed soil media
Organic Matter (%)	3.76	1.85
NO3-N (ppm)	6.5	1.0
NH4-N (ppm)	4.2	4.6
Phosphorus (ppm)	313	315
Potassium (ppm)	247	206
KCl Aluminum (ppm)	1.40	1.08
Calcium (ppm)	2792	1516
Magnesium (ppm)	130	213
Manganese (ppm)	33	49
Boron (ppm)	0.62	1.00
Iron (ppm)	176	244
Copper (ppm)	6.31	4.41
Zinc (ppm)	6.66	5.13

Table 3. Basic information of commercial mycorrhizae

	Micronized Endomycorrhizal Inoculant	MycoApply® Endo	MYKOS
Content	A blend of nine top types of Endo mycorrhizal spores: Glomus aggregatum, G. etunicatum, G. clarum, G. deserticola, G. intraradices, G. monosporus, G. mosseae, Gigaspora margarita, and Paraglomus brasilianum	4 species Endomycorrhizae: Glomus intraradices, Glomus mosseae, Glomus aggregatum, Glomus etunicatum	This single species of arbuscular mycorrhizal fungi contains only Rhizophagus intraradices, formally known as Glomus intraradices. MYKOS does not contain any other microbes such as Trichoderma or ectomycorrhizae.
Description	A minimum of 50 spores per cubic centimeter	60,000 Endomycorrhizal Propagules per lb	Rhizophagus intraradices 300 propagules / gram

AM fungal inoculation treatments:

1. **Micronized Endomycorrhizal Inoculant**
   10 ml
2. **MycoApply Endo**
   Dip in 0.6 g/L solution for 5 sec
3. **MYKOS**
   10 ml
4. **Healthy raspberry field community**
   44.36 ml
5. **Non-inoculated control**
   Mixed soil media