The Use of Biochar and Mineral Wastes to Improve Soil Fertility

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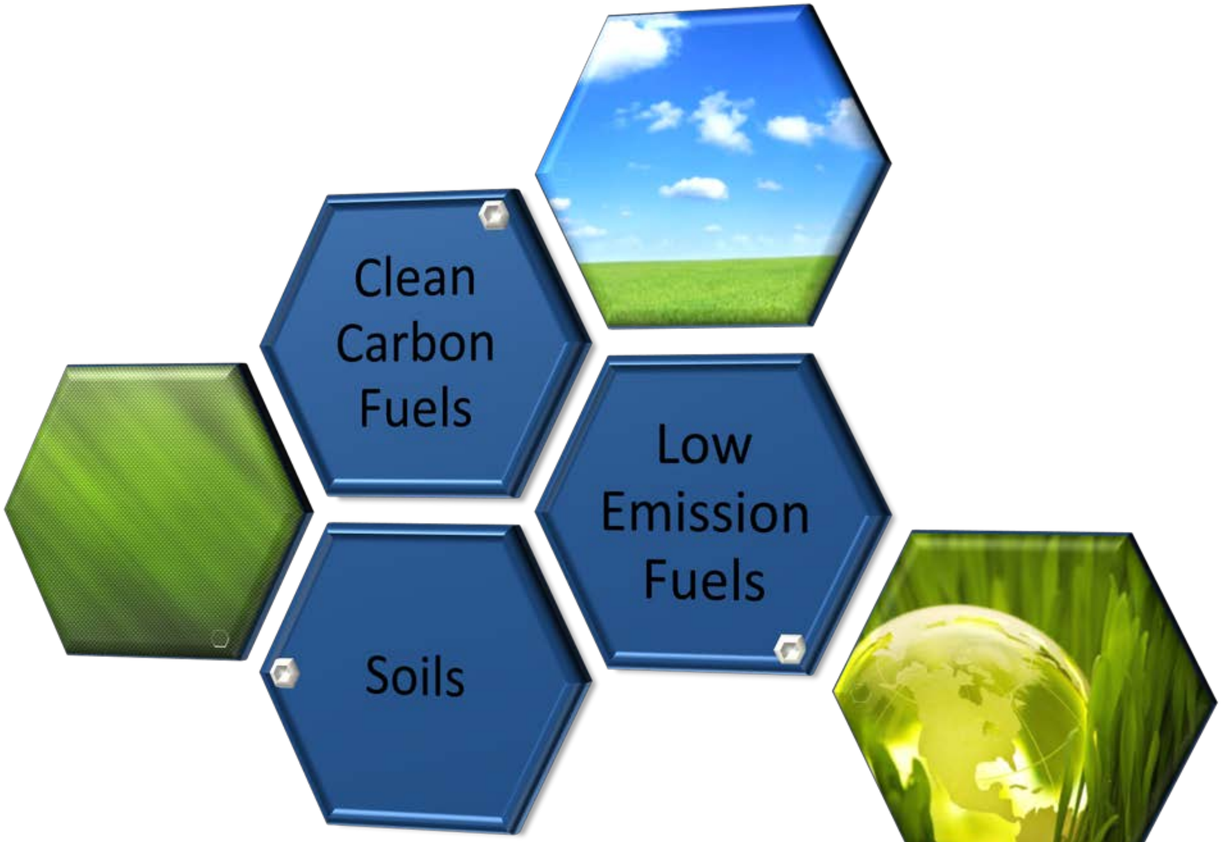
August 2016

Omnis Mineral Technologies
Overview



Omnis Mineral Technologies
Our Vision

Create a sustainable solution to topsoil loss and nutrient depletion in crops.

Transform coalmine waste dumps into land with high environmental, social and/or commercial value.

Supply leading eco-efficient energy and metallurgical feed stocks to industry (ultra-low emission, ultra-low contaminants)

Sustainable Solutions to Topsoil Improvements

- Carbon sequestration
- Fertility
- Physical (texture and structure)
- Water holding
- Remediation

Soil Components

- Soil texture
- Soil structure
- Carbon content
- Microbial husbandry
- Animal husbandry
- Sustainability

Recycling from the Low Energy Well

- Remineralization
  - Mined products
    - Energy extractions (coal)
    - Rock quarries
    - Civil projects (roads/bridges/dams)
- Carbonization
  - Composting
  - Biochar
  - Farm manures and other "agricultural waste" products
  - Biomass from water treatment plants

Present Focus

- Remineralization
  - Mined Products from Energy Extraction (coal)

- Carbonization
  - Biochar

Mineral Matter from Waste Coal Cleanup Sites

Mineral Matter

Clay sized (<2mm) particles of:

- Silica quartz (~30%)
- Iron-Aluminum silicates (K,Mg,Ca,Na) (~50%)
- Mineral salts including macronutrients, micronutrients heavy metals and other earth metals (<5%)
- Highest concentration: calcium, magnesium, potassium, sodium, manganese, zinc and copper
- Lower concentrations of sulfur, phosphorous, boron and manganese
- Heavy metals very low except arsenic which is close to reportable quantities
- Residual coal (<5%) which may act like humates in soil

Primary Mineral Analysis of Mineral Matter

Mineral Analysis:XRD Analysis

Mineral	Chemical Formula	Corbin Approx. wt.%	Spruce Laurel Approx Wt%	Greenfield Approx Wt%
Mica/Illite	$(K,Na,Ca)(Al,Mg,Fe)_2(Si,Al)_4O_{10}(OH,F)_2$	41	39	35
Kaolinite	$Al_2Si_2O_5(OH)_4$	28	18	24
Chlorite	$Mg,Fe,Al)_6(Si,Al)_4O_{10}(OH)$	<5	8	9
Quartz	SiO_2	22	27	20
Calcite	$CaCO_3$	<3	0	5
Pyrite	FeS_2	0	0	<5
Total		91	92	93

50% active mineral (Mica/Chlorite/Calcite). 15-18% usable nutrient such as iron, calcium, magnesium and potassium when converted to a useable form by plants.

Elemental Analysis (ICP AES) (high concentration elements)

Element	**%**
Iron	2.00%
Aluminum	1.50%
Calcium	1.00%
Magnesium	0.50%
Potassium	0.30%
Sulfur	0.30%
Zinc	0.01%
Manganese	0.02%

Heavy Metals in AMP Compared to US and European Standards

EPA 503 Metals	By ICP	AMP	Azomite (COA)	OMRI (mined mineral) Level 1 ppm	503 limit CCL ppm	503 PCL ppm	503 CPLR kg/ha	503 APLR kg/ha/yr	German Soil Protection Rule, clay soils (BodSch, 1998) kg/ha/yr	EPA soil cleanup requirement ppm	NYS Limits for Agriculture ppm	GA NC Limits(limit above which needs to be remediated) ppm
	Arsenic	18	1.1	20	75	41	41	2	0.7			41
	Cadmium	0.61	0.3	40	85	39	39	1.9	0.15	70	0.43	39
	Copper	43	12		4300	1500	1500	75	12	-	270	1500
	Lead	27	6.2	180	840	300	300	15	15	400	200	400
	Mercury	0.07	0.01		57	17	17	0.85	0.1			17
	Molybdenum	1.9	0.23		75							
	Nickel	31	2.6		420	420	420	21	3	1600	72	420
	Selenium	ND	0.7		100	100	100	5				36
	Zinc	93	64.3		7500	2800	2800	140	30	23600	1100	2800
Other EPA metals												
	Chromium	18	6.1							230	11	1200

Not free from heavy metals but generally below US and European Standards

CCL = Ceiling Concentration Limits
PCL = Pollutant Concentration Limits
CPLR = Cumulative Pollutant Loading Rate Limit
APLR = Annual Pollutant Loading Rate Limit
NC = No reportable Concentration

Biochar

Biochar terminology

- Biochar is a term used to describe charred organic matter applied to soil with the intent to improve soil properties *(Lehmann and Joseph, 2009).*
- Popular terms to describe alternate C-enriched residues:
  - *Charcoal, black carbon, char, activated carbon*

Charcoal bricks

Char

Activated C

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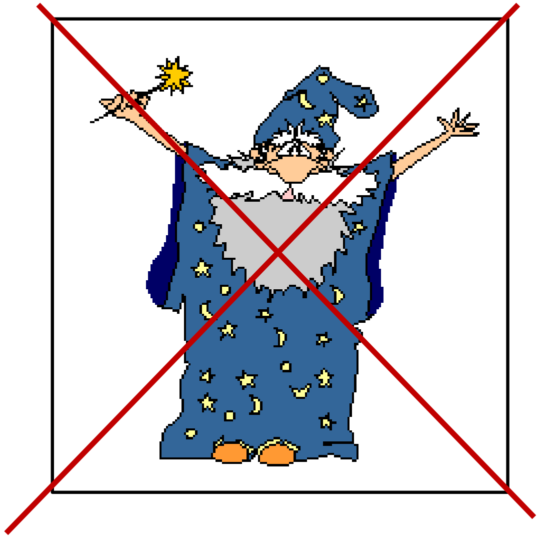
Apply biochar for higher crop yields and soil health improvements



Biochar is not the magic bullet for agriculture but as part of a system it has shown good results

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Biochar Considerations

① All biochars are not created equal for their use as a soil amendment in the agronomic sector.

② Feedstock selection and pyrolysis conditions shapes biochar characteristics.

③ Designer biochars offers the utility of applying the ‘right biochar to the right soil’.

④ Presently focused on one biochar source for proof of concept in synergies of biochar with Omnis Mineral AMP

Navak 2015

Variation in Biochar Properties depending on Source and Soil Modification Characteristics

Biochar chemical characteristics				
Biochar (°C)	**Ash (g/kg)**	**pH (H_2O)**	**C (g/kg)**	**P (mg/kg)**
Poultry litter (350)	**359**	**8.7**	**461**	**29400**
Poultry litter (700)	**524**	**10.3**	**440**	**42800**
Hardwood (500)	**89**	**5.7**	**714**	**0.3**
Soil properties after incubation with 20 g/kg of biochar (127 d)†				
Norfolk + biochar	**CEC (cmol/kg)**	**pH (H_2O)**	**SOC (g/kg)**	**M1-P (mg/kg)**
Control (0 biochar)	**2.1 (0.1)a**	**5.6 (0.0)a**	**3.1 (0.1)a**	**27 (2)a**
Poultry litter (350)	**8.5 (0.6)b**	**8.4 (0.1)b**	**10.7 (0.8)b**	**393 (29)b**
Poultry litter (700)	**13.6 (0.5)c**	**9.0 (0.0)c**	**11.6 (1.4)b**	**714 (31)c**
Hardwood (500)	**2.3 (0.2)a**	**6.6 (0.1)d**	**17.1 (1.1)c**	**22 (2)d**

†*Novak et al. (2009) Ann Env Sci*

Variation in Biochar Characteristics (pH) depending on Source

Feedstock	Pyrolysis (°C)	Mean pH (H_2O)	Source
Wood	400	6.9	
	500	8.8	Singh et al. (2010)
Cow manure	400	9.0	
Hardwood	450	8.8	Jones et al. (2012)
Pecan shell	350	5.9	Novak et al. (2009a)
	700	7.2	
Poultry litter	350	8.7	Novak et al. (2009b)
	700	10.3	
Pine chips	465	6.1	Novak and Busscher (2012)
Corn stover	500	7.2	

As pyrolysis temperature increases, biochar pH can increase

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Growth Trials using AMP and Biochar

- Greenhouse and outdoor trials at USDA to determine efficacy of biochar and mineral matter in improving plant growth and yields
- Spinach was used as an indicator plant due to its relatively short growth cycles
- Biochar from Cool Terra was used to determine proof of concept

Characteristics of Soil Formulations and Inputs

Soil Formulation	**pH**	**CEC**	**Organic Matter %**
Sandy Loam	7.4	5.6	0.5
5% Biochar (C.T)	7.4	5.1	2.6
5% AMP	7.8	6.0	0.8
5% AMP +BC	7.3	4.8	1.6
10% AMP	7.5	6.3	0.6
10% AMP+ BC	7.4	6.1	1.3
Biochar(Cool Terra)	6.9	12	1.5
5% Azomite	7.6	7.4	0.7
Mineral matter	7.9	11	1.3

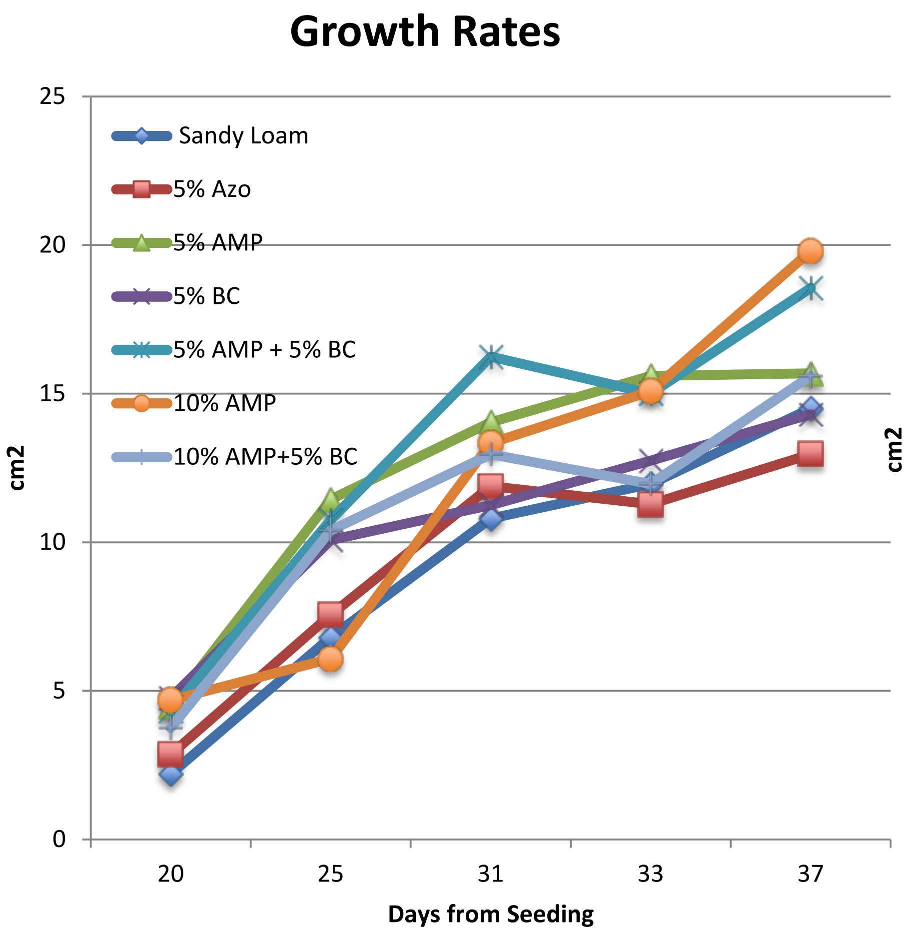
NPK Concentration of Soils and Inputs

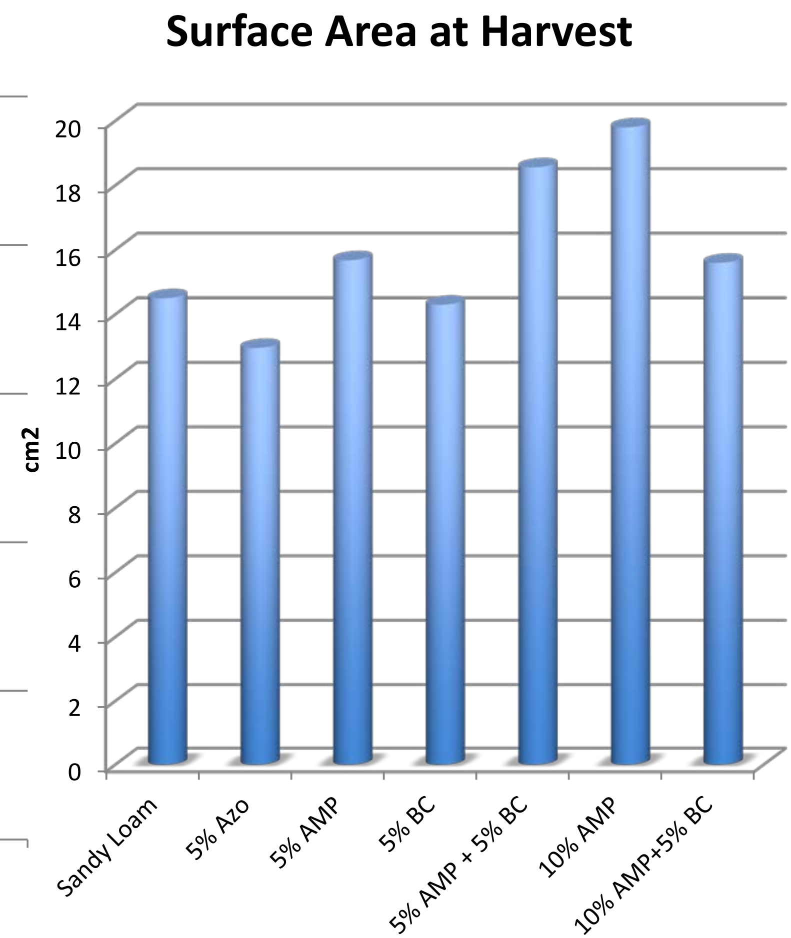
Soil Formulation	Nitrogen -NO3-N.-ppm	Phosphorus NaHCO3-P-ppm	Potassium- K-ppm
Sandy Loam	11	70	148
5% Biochar (C.T)	17	74	177
5% AMP	20	89	162
5% AMP +BC	9	101	246
10% AMP	18	133	159
10% AMP+ BC	12	103	221
Biochar(Cool Terra)	3900	8	5
5% Azomite	8	51	164
Mineral matter	1	3	83

Micronutrients of Soils and Inputs

Soil Formulation	Mg ppm	Ca ppm	Na ppm	S ppm	Zn ppm	Mn ppm	Cu ppm	B ppm
Sandy Loam	134	792	27	9	0.5	1	0.5	0.2
5% Biochar (C.T)	121	710	29	3	0.4	1	0.4	0.1
5% AMP	152	857	21	3	1.2	1	1	0.2
5% AMP +BC	100	637	30	3	0.7	2	1	0.2
10% AMP	141	931	20	4	0.9	3	0.9	0.2
10% AMP+ BC	126	886	29	4	0.8	4	0.7	0.1
Biochar(Cool Terra)	6	23	13	4	24	30	17	4
5% Azomite	137	1148	26	2	0.3	1	0.3	0.1
Mineral matter	189	1828	125	147	1.3	3	2.8	0.4

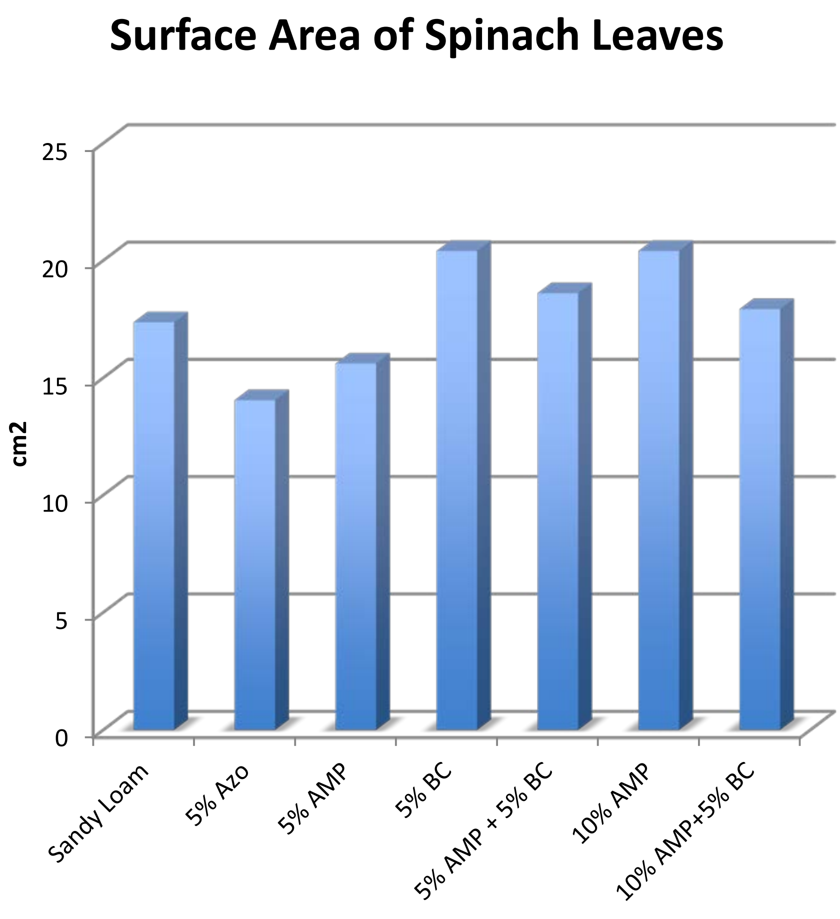
Spinach Surface Area Grown in Amended Soils

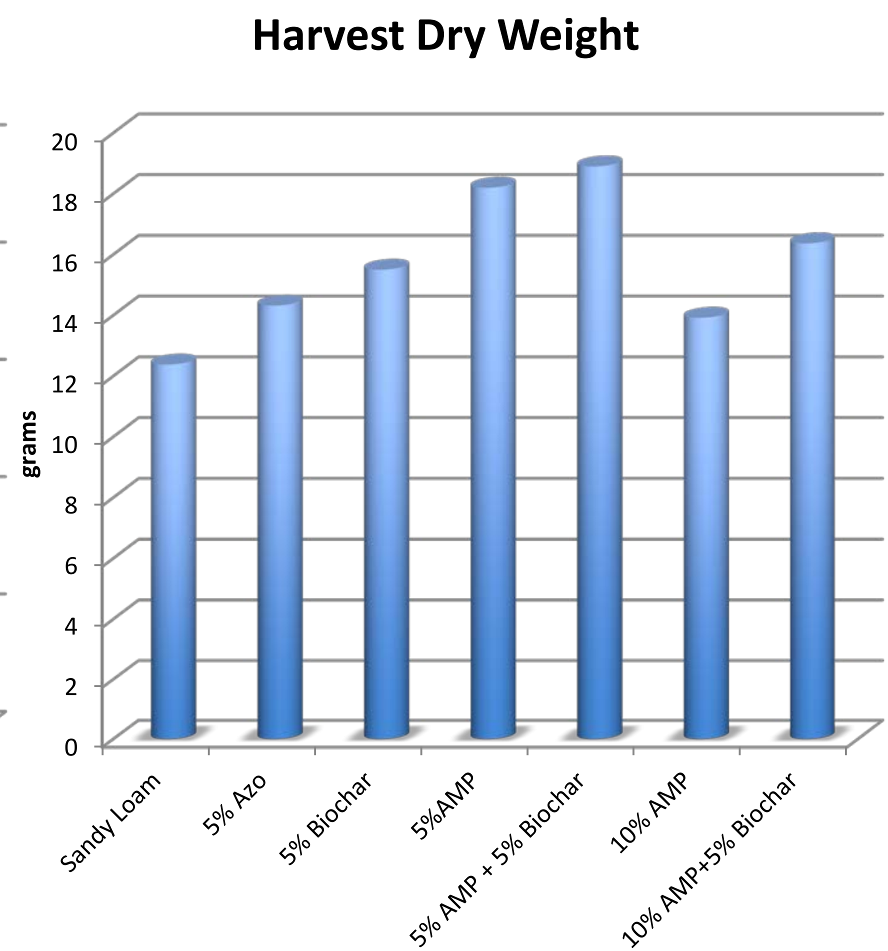




Biochar with Omnis AMP faster growth than either input alone

Harvest Data of Spinach Grown in Amended Sandy Soils





Some Synergies with mineral and biochar

Spinach Grown in Amended Soils with Biochar

Multiple Crops on Mineral/BC Soils

Improvement of yield and vitality using AMP and Biochar
Multiple Outdoor Trial- First Planting

Sandy Loam Control

5% AMP (GF2) + 5% Biochar

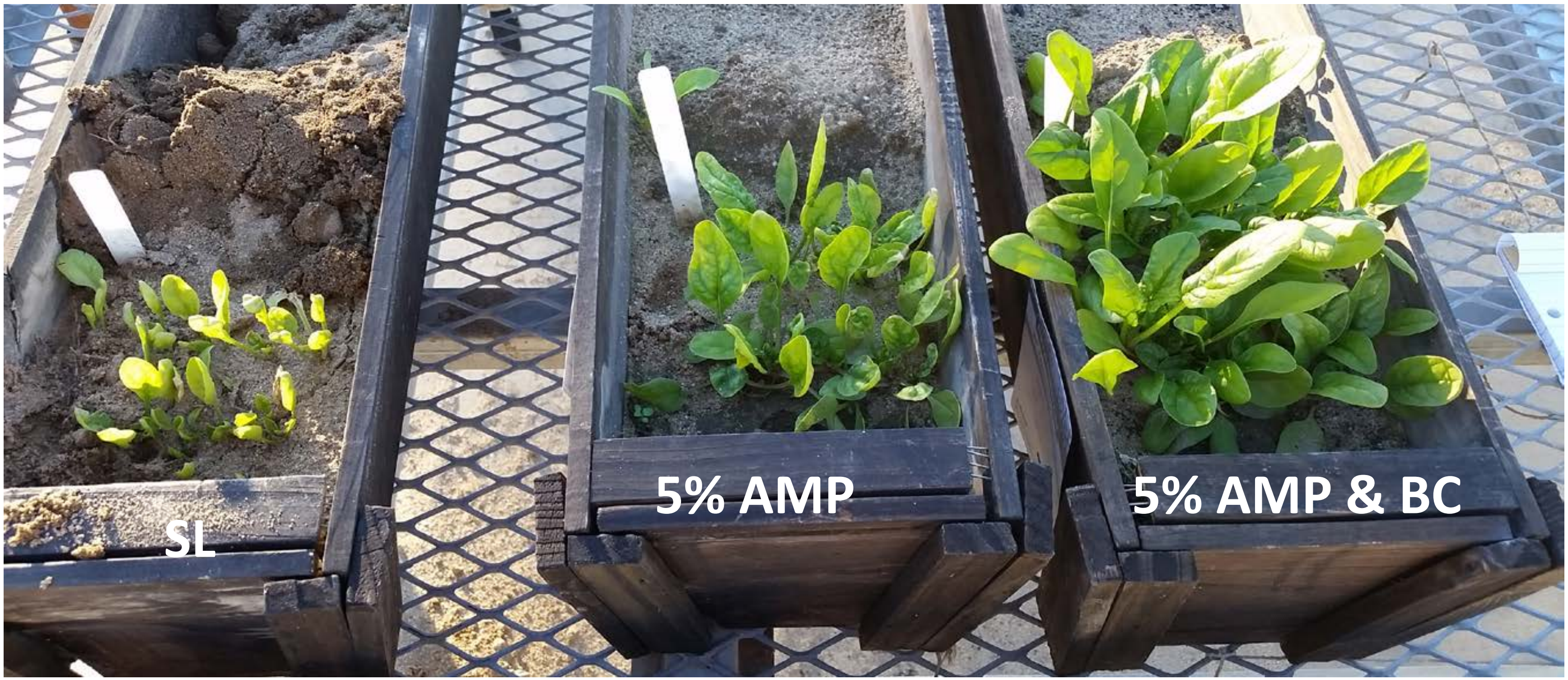
Improvement of yield and vitality using AMP and Biochar

Multiple Outdoor Trial- second planting

Sandy Loam

2.5% AMP and 2.5% Biochar

Improvement of yield and vitality using AMP and Biochar
Multiple Outdoor Trial- third planting



Minimal nitrogen was added three time during the trial under starvation conditions

Conclusions

- Interesting trends worth pursuing more deeply (different crops/soils/biochar as well as in-ground experiments)
- Sandy soils are inherently difficult to farm having a low CEC, high water percolation and low initial nutrient levels
- Biochar and mineral matter both show promise in improving plant health (growth and yields)
- Some synergies are emerging when using AMP with biochar

Future Work

- Continue to determine the best ratios of biochar and mineral as well as introduction of other biomatter (compost and biomass)
- Explore Novak's "designer" biochar concepts (different biochars for different soils)
- Address different crops and different soil types