The 2014 Outdoor Trial of Using Aerobically Digested Poultry Manure to Grow Crops

Poultry Manure Digestate Outdoor Application Project

Report prepared by:

Marc Legault and Nick Savidov

Alberta Agriculture and Forestry
Bio-Industrial Opportunities Branch
Food and Bio Processing Division

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Contents

Executive Summary

The 2014 market garden trial tested the outdoor suitability of Alberta Agriculture and Forestry (AF) greenhouse technologies. Water recycling is typically considered an indoor greenhouse technology. The nutrient solution used to grow outdoor food crops was derived from poultry manure using AF's aerobic digestion technology. Power consumption consisted of the intermittent operation of two 110 vAC pumps to service nearly 150 feet of crop bed. Preliminary considerations suggest these pumps could service a much greater volume of crop bed. Although the trial was limited in duration the results were so promising the trial will be repeated in 2015.

Acknowledgements *(in alphabetical order)*

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Background

This briefing describes the 2014 summer trial of using poultry manure digestate to grow outdoor crops using a soilless 100% water recycling system. Microbially active nutrient fertilizer solutions were derived from diluting the decanted digestate from the aerobic digestion of poultry manure. Pathogen (E. coli) reduction, if not total kill was achieved by fermentation generated pasteurization temperatures. Plants were grown in covered troughs and were fertigated (fertilized / irrigated) using a drip irrigation system.

The trial had a late start [early July] and an early frost termination [mid-September]; the crops were greenhouse nursery produce (hot peppers, string beans, rosemary, tomatoes, cantaloupe, Stevia, thyme and sage). These 'end of the season' transplants quickly regained vigor once transplanted into the system. The outdoor application trialed the culture of rhodiola and forestry seedlings (spruce, pine and hybrid poplar); rhodiola plants will be overwintered in the troughs.

Aerobic Digestion of Poultry Manure

The aerobic digestion / fermentation control process was a manual one; the pH target was to keep the broth below neutral (ideally 6.6 +/- 0.2 pH units). Keeping the pH at this target range would prevent irreversible nutrient loss from phosphate-cation (iron, manganese, calcium) precipitates; nitrogen loss due to ammonification also occurs at basic pH values. The pH was monitored and controlled in the mornings and late afternoons; pH adjustment was more frequent after 'feeding the bioreactor' with poultry manure.

To achieve thermophilic pasteurization temperatures approximately 20 liters of 'moist layer' poultry manure was added for every 100 liters of tap water; total fermentation volumes ranged from 400 to 800 liters. After this pasteurization step nitrogen cycle bacteria need to be re-introduced into the bioreactor by the addition of an appropriate pathogen-free inoculum. Various strategies exist: introduce nutrient feed water, or an aliquot of aquaponics liquid(s), utilize a dedicated N-cycle bacteria/Archaea inoculum (nitrification phase); the poultry manure recycling project is currently assessing these strategies Oct. 2014.

Oxygen was controlled using a manual rotameter to add 90^+ percent oxygen the resulting dissolved oxygen, dO, varied from 3 to 20 mg/L. The use of concentrated oxygen increases the positive redox potential and, therefore, the rate of biochemical processes leading to faster material break-down, however we speculate the use of compressed air would achieve the same results but would require a longer fermentation period. If using compressed air, we recommend feeding the bioreactor a lower (0.1%-0.2% dry) content of organic material to avoid fermentation dO levels below 2 ppm. Using oxygen quickly diminishes the off odours associated with feeding the bioreactor wet (mouldy) poultry manure; the use of air would likely require a longer deodorizing time period.

Agitator was set to have 50 rpm maximum.

Outdoor Trial Description

The outdoor application mirrored the indoor greenhouse techniques:

i. water is fully recycled
ii. the use of soilless culture
iii. drip irrigation technique

The outdoor feed solution was not oxygenated; whereas the indoor substrate culture does have an oxygenated feed solution. The indoor fig culture does not utilize an oxygenated feed solution.

The trial involved testing three different greenhouse soilless substrates (coir, biochar and perlite); also connected to the system was a scouting trial to test a novel substrate. Peat moss was introduced into the system when greenhouse nursery plants were planted into the above substrates.

The trial resembles hydroponics is its use of drip irrigation (2 L/hr per dripper) to water plants grown on soilless substrates. The ARD developed technology differs from hydroponics in deriving its nutrient solutions from poultry manure. Sporadically, synthetic fertilizers were used to supplement the nutrient solutions in calcium, iron and manganese. The incorporation of automated pH control will lessen, if not completely eliminated the need to supplement the nutrient solutions. Since pH control will prevent the irreversible formation of phosphate precipitates that leads to nutrient losses.

The pH paradox associated with using 'organic nutrient' solutions in a hydroponics technique to grow plants was again observed. When using synthetic fertilizers in a hydroponic technique the pH is known to consistently rise to such a degree that acid addition is required due to the preferred uptake of nitrate. In contrast, when using 'organic derived' nutrient solutions the pH has been observed to decrease; often the addition of a basic agent is required. The mechanism(s) of the acidification in the root zone needs to be further investigated; microbial interactions are hypothesized.

Disclaimer: *The terms, 'organic nutrient' and 'organic derived' nutrient solution does not imply an organically certified technique or produce yield. According to current regulations the practice of* *hydroponics technique automatically disqualifies such food production systems from being recognized as organic.*

"The operator shall totally abstain from using hydroponics and aeroponics."

Section 7.5.1 - A Guide to Understanding the Canadian Organic Standards General Principles and Management Standards - Prepared by Canadian Organic Growers; January 2010

The use of pH control agents (acids and bases) may be problematic for those working towards an organic certification.

The substrates were contained in plywood troughs lined with heavy plastic to prevent water leaking losses. Preventing excessive heat in the root zone and ensuring thorough drainage were the two dominate design factors. The troughs were the same width however depth was either 6.5 or 8 inches in order to investigate the effect of substrate volume on crop productivity. A 4inch perforated weeping tile was cut along the length as a means to ensure drainage down the trough in order to recycle the water. The sides and top of the troughs were insulated to prevent root injury from excessive solar heat. Trough construction details are given below.

The troughs' insulation helped significantly reduce heat shock in the root zone with the maximum temperature of 28°C observed only in one occasion. The average temperature in the root zone rarely exceeded 23°C to 25°C; during hot days the feed tank temperature was cooler than the root zone by about 2°C to 3°C. The relatively large capacity feed tank 5m^3 served to buffer against temperature extremes; it cooled during the night and heated slower than the root zone during the day acting as a heat sink. The tank acted as a heat source at night especially critical during early and late season.

An objective was to track sodium concentrations however insufficient data was collected over the short trial duration. The intent was to investigate if sodium would accumulate in the system due its constant addition via poultry manure digestate; the likelihood of sodium buildup is greater for water recycling systems that do not discharge water. Water loss did occur from system leaks and process upsets; such losses remove sodium from the system. Consequently, the hypothesis that microbial activity about the root zone mediates plant sodium uptake (as observed in aquaponics and the indoor poultry manure trials) was not fully investigated.

A scouting exercise to test the feasibility of using a novel substrate as a greenhouse substrate was conducted.

NOTE: *This substrate did not appear to have a negative effect on plant production. However, it is unknown what were, if any, the effects on water quality due to substrate leaching within a closed recycling system.*

Trough depth was either 6" or 8.5" in order to determine if depth impacted plant production given both depths were covered by 5 layers of insulated tarp as a means to protect roots from heat injury.

Equipment and Methods

The wooden plastic lined troughs were placed on tables [32” from the ground]. Four inch weeping tile was cut in half along its length; these weeping tile segments were placed in the bottom of the troughs in order to create a void for the return water. A continuous drip irrigation system was used to water the plants for the purpose of better daytime root temperature control. Five layers of insulated tarp were used to protect the roots from excessive heat. The feed nutrient tank was shaded by an overhead tarp; to avoid heating the nutrient solution. The 5000 liter volume was kept nearly full at all times to maximize the tank’s ability to be a dual heat sink and source throughout the growing season. The return water was first collected in 200 liter barrels; having the overflow discharge (to the sump tank) 2/3’s the way up the barrel prevented substrate fines and grit from entering the pumping assemblies.

The feed pump by means of a pressure tank kept the lines pressurized throughout the growing season with a cut-off pressure of 40 psi; a timer was installed at the end of the trial. Tomato roots were suspected of plugging the return drainage pipe (plugging up with the perlite dust collected on the bottom of the troughs was an alternative suggestion); minimizing water flow was thought to be one means to mitigate water backup and suffocating the plants.

Design Considerations

i. Keeping root zone cool - ideal temperature range: Brassica 16° -20°C; other plants 18° to 24°C; maximum 28°C induces heat shock
ii. Keeping root zone aerated i.e. no stagnant water
iii. Shielding the feed tank from solar heating
iv. Preventing algae growth in the system i.e. opaque tanks and troughs
v. Preventing flooding of the troughs using appropriate substrates, plant density and adequate drainage system

Data Analysis

String beans were a (very) poor crop possibly in part due to the late start and transplant shock since the plants were previously well accustomed to ideal greenhouse conditions. Cantaloupe plants gradually recovered from a similar transfer shock. As mentioned earlier hot peppers were an exceptional crop. Spice crops also performed very well.

Conclusions

Plant Trials Utilizing Poultry Manure Digestate

Biochar was the best performing substrate followed by coconut coir and perlite. Perlite generally performed poorly in the trials.

System Performance

Overall, the results from summer outdoor trial were very promising despite of the short period of the trial and leaking problems.

There was no statistically significant difference between shallow and deep troughs. However, there was a trend with perlite-grown plants performing better in shallow troughs and biochar-grown plants showing better results in deeper troughs. The speculation is that the steeper water retention curve of perlite did not provide adequate water supply in deeper troughs, while the plant roots reached water-saturated bottom of the trough faster in shallow troughs.

Process and System Improvements

i. Robust trough design [preformed plastic or metal troughs]
ii. Robust water drainage [it appeared tomato roots blocked the troughs]
iii. Provision for frost protection
iv. Winter protection design considerations i.e. maximize the system's reuse
v. Wind protection [fence, lower plant height, etc.]

One suggestion is to place plant troughs into ground trenches for better temperature control.

Robust irrigation timers to dispense nutrients as require per production; continuous drip for vegetable production and intermittent irrigation to encourage plant expression of nutraceutical compounds i.e. stress induced expression.

Outdoor Trial 2014

Equipment and Materials

Item	Service	Make	Model	Voltage	Amps	Horse-power	Cost Range		Notes
1	Irrigation Feed Pump	Little Giant	JP-050-C	115 / 230 vAC	9 / 4.5 A	1/2	$350	$500	Intermittent service
2	Return Water Pump	Rigid	SP1000	120 vAC	9.8 A	1	$200	$300	Sump pump Intermittent service
3	Insulated Bioreactor	Zeebest Plastic	1000 L hopper				$2,000	$3,000	plastic hopped tank w/ bottom valve
4	Pressure Tank ___ L						$300	$500	
5	Drippers and Feed Lines						$200	$500	
6	5000 L Feed Storage Tank	Zeebest Plastic					$1,000	$1,500	
7	Pressure Relief Valve						$100	$150	
8	Troughs						$1,000	$3,000	
9	Miscellaneous pumps, drums, piping, timers etc.						$700	$2,000	
10	Benches						$1,000	$2,000	
11	Insulation material						$200	$400	
12	Horticultural supplies (transplants, pots, substrates, etc.)						$500	$1,000	
	System Hardware and Supplies Costs						**$5,000**	**$11,050**	

(excluding oxygen concentrator or air blower costs)

Equipment Considerations

- All vessels, piping and troughs etc. must be opaque to avoid algae growth.
- **5000 L nutrient feed tank** – opaque to prevent algae growth and painted white to reflect solar energy.
- **Substrate troughs** were constructed from wood and plastic lined;
  Outside dimensions:
  i. Width 13” x Depth 8.5” x 69' length - East Location
  ii. Width 13” x Depth 6.5” x 72' Length - West Location

Garden Market Outdoor Trial Layout

Extra Plots				1	2	3	4	5	6	7	8	9	Extra Plots			
				2	1	3	2	1	3	2	1	3				

				3	2	1	3	2	1	1	3	2				
Extra Plots				10	11	12	13	14	15	16	17	18	Extra Plots			

Plot Treatment:

1	Coir-control
2	Perlite
3	Biochar

	Pepper yield, kg/plot	SE, standard error
Coir	2.02	0.13
Perlite	1.54	0.16
Biochar	2.10	0.17

Comments:

- Length of the lot is 1.5 m
- The rest lots are filled with perlite
- Crop to be determined
- 3 Pepper plants per plot (Yellow Wax and hot pepper)
- 3 Rhodiola plants per plot

Garden Market Outdoor Trial

Pepper Harvest

June 24 2014 : Pepper Transplanted first harvest : July 14 2014

Treatment:			
	1	Coir-control	3 Pepper (yellow wax and hot pepper) plants per plot
	2	Perlite	3 Rhodiola plants per plot
	3	Biochar	

Plot #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Treatment	2	1	3	2	1	3	2	1	3	3	2	1	3	2	1	1	3	2
date 2014	weight gram	weight gram	weight gram	weight gram	weight gram	weight gram	weight gram	weight gram	weight gram	weight gram	weight gram	weight gram	weight gram	weight gram	weight gram	weight gram	weight gram	weight gram
July. 14	0	41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
July. 18	0	0	26	0	28	0	32	25	39	0	18	48	15	31	61	36	27	38
July. 28	46	42	21	31	15	56	44	62	0	0	0	20	79	0	0	28	28	0
Aug. 11	0	71	108	226	57	59	166	50	254	178	335	0	291	0	219	217	81	0
Aug. 18	230	200	420	323	355	237	246	372	345	297	295	314	417	118	255	341	380	115
Aug. 29	549	541	512	645	512	282	631	736	700	948	693	777	834	384	416	701	639	208
Sept. 5	332	337	405	138	369	247	253	444	508	309	370	372	427	204	345	225	420	275
Sept. 11	461	635	437	149	285	453	451	582	345	690	344	555	439	441	498	947	654	403
Total Weight grams	1,618	1,867	1,929	1,512	1,621	1,334	1,823	2,271	2,191	2,422	2,055	2,086	2,502	1,178	1,794	2,495	2,229	1,039

Total Weight **33,966 grams of peppers**

Perlite troughs (extra trough space) before and after the experimental plots

		55 yellow wax pepper	33 Hot pepper	
date2014		weight(g)	weight(g)	
July. 14		354		
July. 18		172		
July. 28		246		
Aug. 11		1327		
Aug. 18		396		
Aug. 29		1,195	621	
Sept. 5		6,075	349	
Sept. 11		5,173	1,449	
Total Weight grams		**14,938**	**2,419**	

Garden Market Outdoor Trial

Pepper Harvest

June 24 2014 : Pepper Transplanted

first harvest : July 14 2014

Harvest Data for all Plots and Trough Depths

	Pepper yield, kg/plot	Standard Error
Coir	2.02	0.13
Perlite	1.54	0.16
Biochar	2.10	0.17

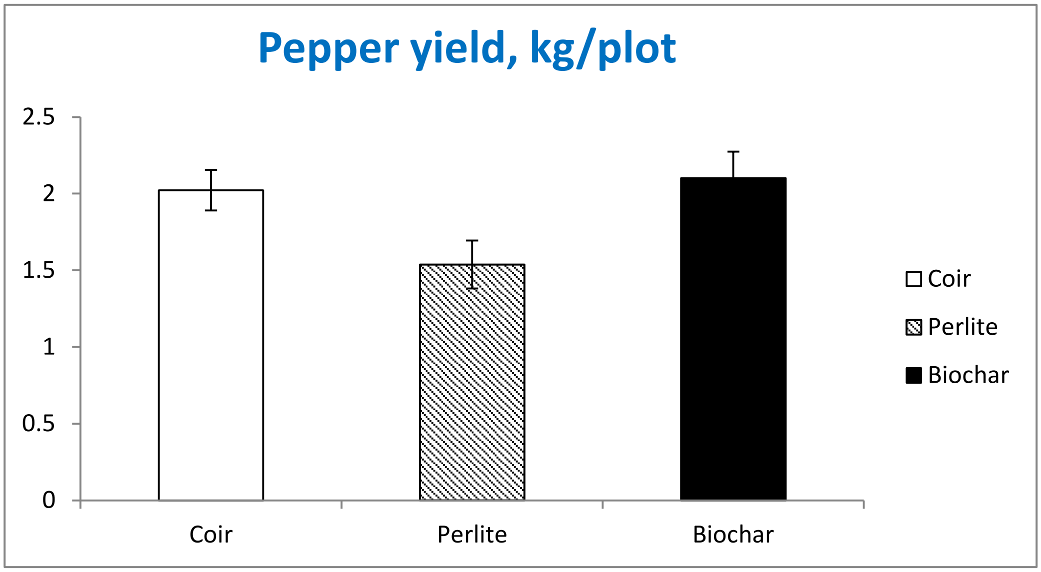
	Trough Depth			
Substrate	Shallow 6.5"	Standard Error	Deep 8"	Standard Error
Coir	1.92	0.33	2.13	0.35
Perlite	1.65	0.16	1.42	0.55
Biochar	1.82	0.44	2.38	0.14

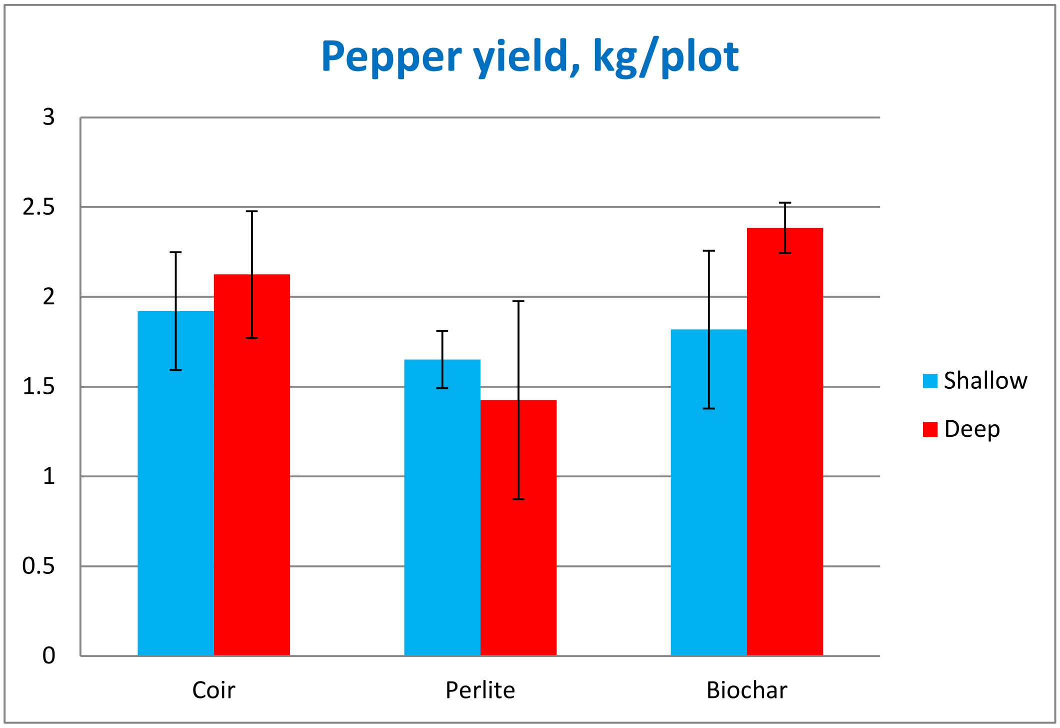
Conclusion

Biochar was the best performing substrate followed by coconut coir and perlite. Perlite generally performed poorly in the trials.

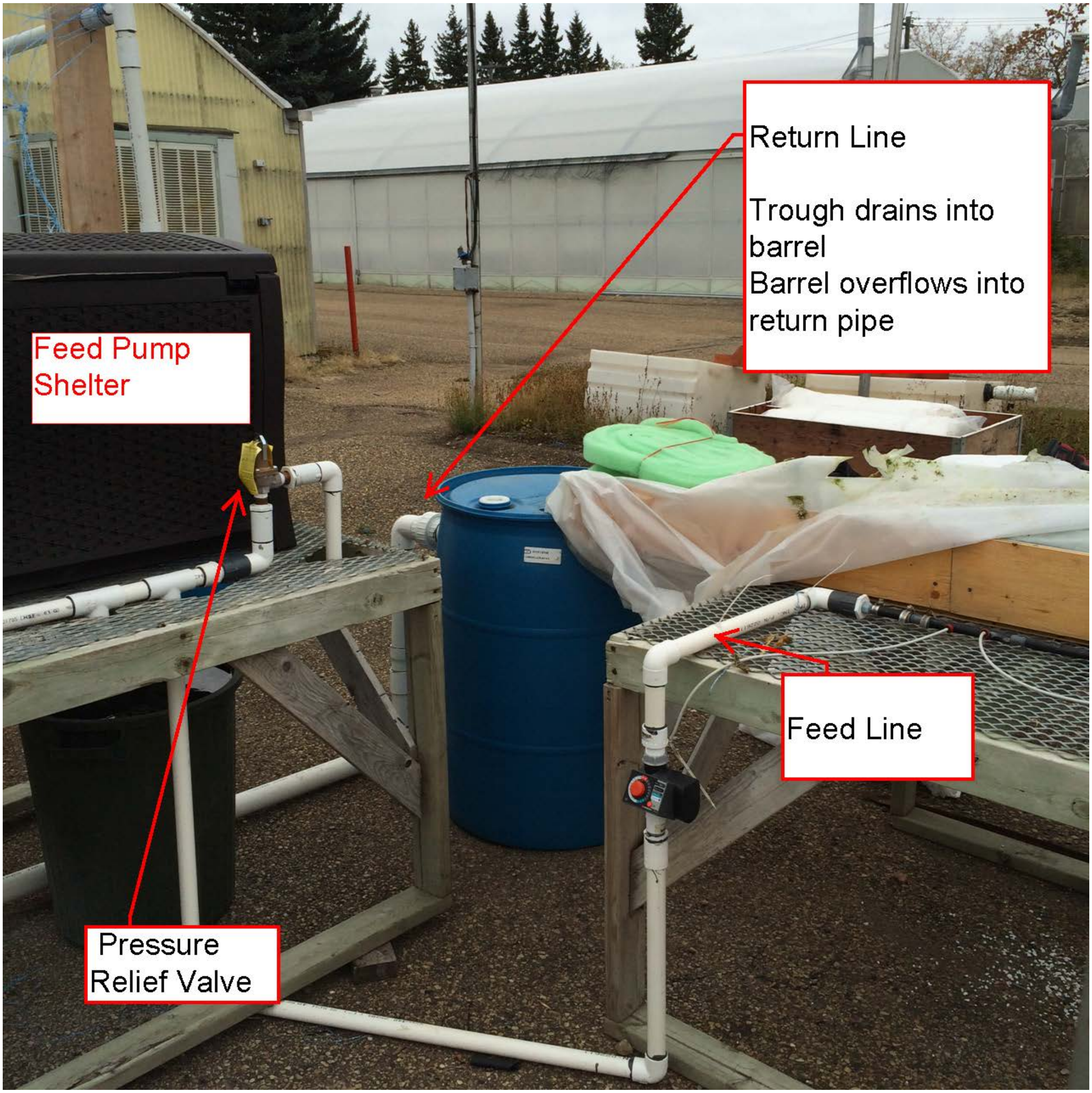
Overall, the results from summer outdoor trial were very promising despite of the short period of the trial and leaking problems. There was no statistically significant difference between shallow and deep troughs. However, there was a trend with perlite-grown plants performed better in shallow troughs and biochar-grown plants showing better results in deeper troughs. The speculation is that the steeper water retention curve of perlite did not provide adequate water supply in deeper troughs, while the plant roots reached water-saturated bottom of the trough faster in shallow troughs

Pepper Yield





Outdoor Layout - Photo



Outdoor Peppers - Photo

Contact Information

Contact Marc Legault or Nick Savidov with Alberta Agriculture and Forestry at biobranch@gov.ab.ca for more information on the Poultry Manure Digestate Outdoor Application Project.