Table 1. Total rainfall (mm) and average daily air temperature (ºC) for the Horticulture Research Station, Ames, IA for the months April –November 2017, 2018, and 2019

Month	Air Temp (ºC)			Precipitation (mm)		
	2017	2018	2019	2017	2018	2019
April	11.1	5.1	10.3	102.1	45.0	59.7
May	15.4	20.1	14.7	132.8	90.7	180.3
June	22.3	23.4	21.3	75.9	234.7	93.7
July	24.1	23.3	23.8	84.1	58.7	84.8
August	20.1	22.5	20.8	62.0	177.0	40.4
September	19.7	18.8	20.6	49.3	49.3	153.2
October	11.7	9.5	7.9	154.9	86.9	142.2
November	2.9	-0.5	0.3	7.9	46.2	35.1
Total (April – Nov.)				669	788.4	789.4

Table 2. Selected soil properties sampled 3, March 2017 before the start of the study at 0-15(cm).

Soil Property	
P (mg kg soil)	38.0
K (mg kg soil)	213.0
Mg (mg kg soil)	213.0
Ca (mg kg soil)	1699.0
pH	6.3
CEC (meq/100g)	2.8

Table 3. Description of the three rotations and field activities carried out at the Iowa State University Department of Horticulture greenhouses and Horticulture Research Station Ames, IA in 2017, 2018, and 2019. V-P-CC = vegetable-chicken-cover crop, V-CC-P = vegetable-cover crop-chicken, and V-CC = vegetable-cover crop-vegetable.

	Year								
	2017			2018			2019		
	Rotation								
	V-P-CC	V-CC-P	V-CC-(V)	V-P-CC	V-CC-P	V-CC-(V)	V-P-CC	V-CC-P	V-CC-(V)
Event									
Vegetable seeding in greenhouse	----------3 March----------			--------8 March-----	16 March	-	-	-	
Initial soil sampling of whole field	----------4 March----------			-	-	-	-	-	-
Soil sampling (*early spring*)	----------26 March----------			----------30 March----------			----------1 April----------		
Collection of cover crop biomass	----------			19 April	-	-	15 April	-	-
†Vegetable seeding/transplanting	----------17 April----------			----------24 April---------		16 May	----------16 April ----------		
Vegetable harvest	----------July 1----------			----------29 May – 14 June-----		17 July – 26 Sept	----------29 May- 11 June----------		
Soil sampling (*early summer*)	----------11 July----------			----------18 June----------			----------6 June----------		
▲Chicken integration	10 July	-	-	28 June	-	-	11 June	-	-
*Cover crop seeding	-	----------11 July--------		-	18 June	19 May	-	----------1 July---------	
Vegetable seeding in greenhouse	-	-	17 Aug	-	-	-	-	-	-
Chicken removal	30 August	-	-	8 August	-	-	17 July	-	-
Soil sampling (*mid-late summer*)	----------30 Aug----------			----------10 Sept----------			----------6 August----------		
▪Cover crop seeding	30 Aug	-	-	8 August	-	-	6 Aug	-	-
Collection of cover crop biomass	-	-	12 Sept	-	17 Aug	-	-	----------6 Aug----------	
⁑Vegetable seeding/transplanting	-	-	13 Sept	-	-	-	-	-	Aug 7
Chicken integration	-	15 Sept	-	-	7 Sept	-	-	6 Sept	-
Chicken removal	-	8 Nov	-	-	20 Oct	-	-	31 Oct	-
Vegetable harvest	-	-	9 Nov	-	-	-	-	-	30 Oct
Soil Sampling (*fall*)	----------14 Nov----------			----------20 Oct----------			----------31 Oct----------		

† 2017 = (*Brassica Oleraceae* var. Italica cv. 'Belstar'(Seedway Hall, NY), 2018 = (*Lactuca Setiva* cv Freckles, Green Towers (High Mowing Organic Seeds, Walcott, VT), Jericho, Coastal star, and Paris Island (Johnny's Seeds, Winslow, ME) and (Capsicum annum cv. Milena, King of the north, Golden California wonder, California wonder, Sweet chocolate), 2019 = *Spinacia oleracea* cv Corvair, Acadia (Johnny's Seeds, Winslow, ME), Regiment, Butterflay, Renegade (High Mowing Organic Seeds, Walcott, VT).

*mixture of crimson clover (Trifolium incanatum) (Green Cover Seed, Bladen , NE) and oats (Avena sativa, Albert Lea Seeds, Albert Lea, MN)

▪ (*Secale cereal, cv Variety not stated,* Albert Lea Seed, Albert Lea MN)

⁑2017 = Lactuca Setiva cv. Holon (Johnny's Seeds, Winslow, ME), 2019 = *Daucus carota* cv Negovia, Yaya, Napoli (Johnny's Seeds, Winslow, ME), Miami (High Mowing Organic Seeds, Walcott, VT), Nantes fancy (Fedco Seeds Clinton, ME)

▲2017 = red ranger chicken (RR) (Welp Hatchery Bancroft, IA), 2018 and 2019 = Imperial chickens (IC) (Moyer's, Quakertown, PA)

Table 4. Total C and N and C:N of cover crops used in the rotations. Oat and crimson clover biomass collected from both V-CC-P and V-CC rotations on 6 August 2019 and Rye biomass collected from V-P-CC on 15 April 2019 and ground to 1mm using a Thomas Wiley Laboratory Mill (Thomas Scientific, Philadelphia PA). Oat and crimson clover dry weights are the average of cover crop biomass collected from both V-CC-P and V-CC rotations on 12 September 2017 and 6 August 2019 and Rye dry weight collected from V-P-CC on 19 April 2018 and 15 April 2019 in t/ha. V-P-CC = vegetable-chicken-cover crop, V-CC-P = vegetable-cover crop-chicken, and V-CC = vegetable-cover crop-vegetable.

Cover crop	%C	% N	C:N	Dry weight t/ha
Oats	30.55	2.7	16.7	0.4
Crimson Clover	34.4	2.2	16.1	0.3
Rye	33.9	3.4	9.8	0.5

Table 5. Biolog Ecoplate™ carbon source guild groupings

Well no.	ID	C-source	C grouping
Well 1	C0	Water (blank)	
Well 2	C1	Pyruvic acid methyl ester	Carbohydrate
Well 3	C2	Tween 40	Polymers
Well 4	C3	Tween 80	Polymers
Well 5	C4	α-Cyclodextrin	Polymers
Well 6	C5	Glycogen	Polymers
Well 7	C6	D-cellobiose	Carbohydrate
Well 8	C7	α-D-Lactose	Carbohydrate
Well 9	C8	β-Methyl-D-Glucoside	Carbohydrate
Well 10	C9	D-Xylose	Carbohydrate
Well 11	C10	i-Erythritol	Carbohydrate
Well 12	C11	D-mannitol	Carbohydrate
Well 13	C12	N-Acetyl-D-Glucosamine	Carbohydrate
Well 14	C13	D-glucosaminic acid	Carboxylic and acetic acids
Well 15	C14	Glucose-1-Phosphate	Carbohydrate
Well 16	C15	D,L-α-Glycerol Phosphate	Carbohydrate
Well 17	C16	D-Glactonic Acid γ-lactone	Carboxylic and acetic acids
Well 18	C17	D-Galacturonic Acid	Carboxylic and acetic acids
Well 19	C18	2-Hydroxy Benzoic Acid	Carboxylic and acetic acids
Well 20	C19	4-Hydroxy Benzoic Acid	Carboxylic and acetic acids
Well 21	C20	γ-Amino Butyric Acid	Carboxylic and acetic acids
Well 22	C21	Itaconic Acid	Carboxylic and acetic acids
Well 23	C22	α-Ketobutyric Acid	Carboxylic and acetic acids
Well 24	C23	D-Malic Acid	Carboxylic and acetic acids
Well 25	C24	L-arginine	Amino acids
Well 26	C25	L-asparagine	Amino acids
Well 27	C26	L-phenylalanine	Amino acids
Well 28	C27	L-serine	Amino acids
Well 29	C28	L-threonine	Amino acids
Well 30	C29	Glycyl-L-glutamic acid	Amino acids
Well 31	C30	Phenyl ethylamine	Amines and amides
Well 32	C31	Putrescine	Amines and amides

Table 6. Total weight (kg), total number, marketable weight (Kg) and marketable number, dry weight (g), head length (cm), and head diameter (cm) from lettuce harvested from V-P-CC and V-CC-P treatments in June 2018 at ISU Horticulture Research Station Ames, IA. V-P-CC = vegetable-chicken-cover crop, V-CC-P = vegetable-cover crop-chicken. Head length, diameter was measured from five marketable heads and averaged. Dry weight was the total weight of five marketable heads averaged over the five heads.

	Total weight	Total number	Marketable weight	Marketable number	Head dry weight	Head length	Head diameter
Rotation							
V-P-CC	123.0a	245a	64.7b	108b	43.1a	36.8a	25.3b
V-CC-P	130.5a	242a	101.5a	172a	38.0a	36.1a	32.2a

Values with the same letters are not statistically different at $p<.05$

Table 7. Total, marketable, and dry weight (g) of spinach harvested from all rotations V-P-CC. V-CC-P, and V-CC from May-June 2019 at ISU Horticulture Research Station Ames, IA. V-P-CC = vegetable-chicken-cover crop, V-CC-P = vegetable-cover crop-chicken, and V-CC = vegetable-cover crop-vegetable. Data was collected from a 1.5m section of one center row of each of the five beds totaling 7.5m harvested.

	Total weight	Marketable weight	Dry weight
Rotation			
V-P-CC	262.7 NS*	254.3 NS*	34.7 NS*
V-CC-P	382.5	365.0	49.6
V-CC	310.0	296.1	42.0

NS* = not statistically significant

Table 8. Soil macro and micronutrients, and selected soil properties tested from four sampling dates over three years for each rotation. Sampled at 0-15(cm). Rotations = V-P-CC (vegetable-chicken-cover crop, V-CC-P (vegetable-cover crop-chicken), and V-CC (vegetable-cover crop).

Sampling time	Year		Soil nutrients														Other soil Properties		
			NH_4-N	NO_3-N	Total N	P	K	Mg	Ca	S	Na	Zn	Fe	Cu	B	Mn	pH	CEC	OM
									(mg kg soil)									(meq/100g)	%
At planting	2017	Rotation																	
		V-P-CC	2.6	7.3	9.9	40.5	151.7	301.7	1678.5	-	-	-	-	-	-	-	6.2	12.9	3.2
		V-CC-P	2.6	8.2	10.8	41.5	125.5	313.0	1603.7	-	-	-	-	-	-	-	6.2	12.3	2.9
		V-CC	2.8	7.7	10.5	37.2	119.0	302.5	1634.7	-	-	-	-	-	-	-	6.2	12.4	3.2
	2018																		
		V-P-CC	2.7b	0.07b	2.77b	68.7	250.2	482.4	2311.9	6.7a	8.6a	2.9	-	-	-	-	6.8	15.2	3.6
		V-CC-P	33.2a	12.7a	45.9a	86.3	368.4	469.4	2278.2	8.6b	15.9b	3.4	-	-	-	-	6.5	14.9	3.8
		V-CC	2.3b	1.4b	3.7b	78.4	284.7	490.6	2171.8	6.4a	10.0a	2.2	-	-	-	-	6.8	14.4	3.6
	2019																		
		V-P-CC	2.7	9.8	12.5	69.9	287.4	389.8	1779.4	6.8	8.8	2.6	-	-	-	-	7.0	11.8	3.3
		V-CC-P	3.4	10.1	13.5	66.8	223.8	433.0	1883.8	6.9	9.3	2.1	-	-	-	-	6.9	12.8	3.2
		V-CC	4.1	10.5	14.6	69.7	225.7	457.9	2016.4	7.3	10.3	2.2	-	-	-	-	7.0	13.3	3.1
After harvest	2017																		
		V-P-CC	5.3	3.8	9.1	51.7	139.3	293.1	1649.2	-	-	-	-	-	-	-	6.6	11.6	2.9
		V-CC-P	4.0	3.5	7.5	58.5	188.0	297.7	1654.0	-	-	-	-	-	-	-	6.4	12.1	2.9
		V-CC	4.0	4.2	8.2	77.3	179.3	292.0	1653.8	-	-	-	-	-	-	-	6.4	12.1	2.9
	2018																		
		V-P-CC	4.4	7.6b	12.0	90.1	210.2	513.8	2241.2	9.9	12.1	3.8a	174.5a	2.2	0.7	77.2	6.9	14.8	3.3
		V-CC-P	3.4	11.8a	15.2	88.1	260.7	476.2	2096.2	7.4	12.0	3.2b	199.8b	2.1	0.7	57.8	6.8	13.9	3.4
		V-CC	3.7	4.0c	7.7	95.2	242.8	481.4	2059.6	8.8	12.2	2.5c	201.7b	2.1	0.7	58.6	6.9	13.7	3.3
	2019																		
		V-P-CC	3.4	9.6	13.0	97.9	239.8	480.9	2316.4	7.4	11.1	4.2a	190.2a	2.5	0.9	78.3	6.9	15.0	3.1
		V-CC-P	1.9	7.0	8.9	96.9	318.1	464.4	2245.3	7.3	14.2	3.8a	223.8b	2.6	0.8	65.8	6.6	14.7	3.2
		V-CC	2.2	7.3	9.5	93.3	268.3	476.2	2113.4	7.9	11.7	2.6b	221.6b	2.6	0.8	67.9	6.7	14.0	3.1

*values with the same lower case letters within sampling time and year are not significantly different ($P<0.05$). – indicates this property was not tested at a particular sampling time.

Table 8. Soil macro and micronutrients, and selected soil properties tested from four sampling dates over three years for each rotation. Sampled at 0-15(cm) Rotations = V-P-CC (vegetable-chicken-cover crop, V-CC-P (vegetable-cover crop-chicken), and V-CC (vegetable-cover crop). *continued*

Sampling time	Year		Soil nutrients														Other soil Properties		
Mid-Summer	2017		NH_4-N	NO_3-N	Total N	P	K	Mg	Ca	S	Na	Zn	Fe	Cu	B	Mn	pH	CEC	OM
		Rotation	(mg kg soil)															(meq/100g)	%
		V-P-CC	1.9	4.7	6.6	52.8	204.4	456.1	2152.9	11.1	14.7a	2.4	-	-	-	-	6.4	14.4	3.1a
		V-CC-P	2.3	2.7	5.0	58.7	272.7	472.2	2216.6	9.6	8.9b	2.1	-	-	-	-	6.5	14.7	3.2a
		V-CC	1.7	2.6	4.3	61.1	268.5	452.4	2118.5	10.1	9.9b	1.9	-	-	-	-	6.5	14.1	3.6b
	2018																		
		V-P-CC	7.2b	21.8a	29.0a	86.8	233.0	457.2	2192.6	7.9	13.5a	3.5	166.2	2.0	0.9	65.8	6.7	14.1	3.2
		V-CC-P	3.0a	10.9b	13.9b	77.4	252.7	483.3	2270.3	6.1	9.0b	2.8	195.2	2.1	0.9	51.7	6.7	14.7	3.3
		V-CC	2.9a	11.1b	14.0b	91.4	255.3	504.6	2187.4	6.8	9.4b	2.4	201.0	2.3	0.9	57.1	6.8	14.6	3.1
	2019																		
		V-P-CC	4.6a	11.0a	15.6a	127.3	348.3	543.1	2443.4	13.3a	22.5a	5.1a	193.1	2.2	0.9	77.7	7.0	16.2	3.2
		V-CC-P	2.1b	5.5b	7.6b	99.1	323.6	506.4	2367.2	8.0b	13.7b	3.4b	200.6	1.9	0.8	66.4	6.9	15.5	3.2
		V-CC	2.5b	5.2b	7.7b	108.5	329.0	535.1	2323.6	8.0b	12.1b	2.5b	202.7	1.8	0.8	70.6	6.9	15.5	3.1
End of Season																			
	2017																		
		V-P-CC	4.4	0.9a	5.3	67.0	228.1	423.0	1953.4	7.3a	9.2	2.7	-	-	-	-	6.6	13.0	3.4a
		V-CC-P	1.8	5.5b	7.3	42.1	192.6	383.6	1826.7	8.7b	10.5	1.5	-	-	-	-	6.5	12.3	2.9b
		V-CC	6.3	1.3a	7.6	56.0	169.3	445.2	1786.8	7.4ab	9.1	1.5	-	-	-	-	6.6	12.0	3.2a
	2018																		
		V-P-CC	12.3	4.1	16.4	91.1	344.9	481.0	2058.4	6.5	14.3	2.9	190.3	2.0	0.8	55.0	6.8	14.0	3.2
		V-CC-P	10.4	2.3	12.7	82.1	338.8	456.3	2039.3	6.6	12.2	2.9	182.8	2.1	0.8	65.2	6.8	13.7	3.1
		V-CC	3.8	3.2	7.0	82.3	261.7	489.9	2137.5	5.7	8.7	2.9	179.8	1.7	0.9	58.9	6.9	14.2	3.3
	2019																		
		V-P-CC	2.3	21.0a	23.3	102.9	270.2	524.0	2349.3	8.0	12.3	4.4	154.2	2.2	0.7	64.7	6.9	15.7	3.0
		V-CC-P	1.3	37.2b	38.5	110.0	390.0	523.0	2429.0	9.3	14.5	4.4	190.9	2.5	0.7	56.5	6.5	16.4	3.2
		V-CC	1.7	17.9a	19.6	119.8	333.2	550.1	2283.5	8.3	16.1	3.5	177.0	2.7	0.7	50.3	6.7	15.8	3.0

*values with the same lower case letters within sampling time and year are not significantly different (P<0.05).– indicates this property was not tested at a particular sampling time.

Table 9. Principal component loadings (correlation between original loading variable and principal component) as a measure of influence of a loading variable on overall treatment differences

	Year					
Loading variable	2017		2018		2019	
	PC1(63.7)[a]	PC2(22.2)	PC1(39.3%)	PC2(25.7%))	PC1(63.7%)	PC2(15.1%)
Amines/amides	0.51	-0.12	0.48	-0.02	0.41	-0.22
Amino acids	0.21	0.86	0.60	-0.12	0.42	0.70
Carbohydrates	0.46	-0.47	-0.11	-0.75	0.43	-0.66
Carboxylic and acetic acids	0.47	0.19	0.21	0.62	0.52	0.14
Polymers	0.51	0.01	-0.59	0.22	0.45	0.02

[a] Percent of total variance in data set, including all cover crop/compost treatments, attributed to principal component 1 (PC1) and 2 (PC2). A high positive or negative correlation indicates higher degree of influence of loading variable on differences among treatments determined for a principal component

Table 10. Soil and spinach samples analyzed for presence of *E. coli* O157:H7 and *Salmonella* spp. using the standard testing protocols for mini Vidas ECPT® and SPT®.

		Soil tests										Spinach tests	
		2 November 2018			8 April 2019				5 November 2019			5 June 2019	
Rotation	Replication	*E. coli* O157:H7	*Salmonella spp.*	Confirmation - *Salmonella*	*E. coli* O157:H7	Confirmation - *E. coli* O157:H7	*Salmonella spp.*	Confirmation - *Salmonella*	*E. coli* O157:H7	Confirmation - *E. coli* O157:H7	*Salmonella spp.*	*E. coli* O157:H7	*Salmonella spp.*
V-P-CC	1	ND	ND	ND	*Positive*	*Positive*	ND	ND	ND	ND	ND	ND	ND
V-P-CC	2	ND	ND	ND	*Positive*	*Positive*	ND	ND	ND	ND	ND	ND	ND
V-P-CC	3	ND	ND	ND	ND	*Positive*	ND	ND	ND	ND	ND	ND	ND
V-P-CC	4	ND	ND	ND	*Positive*	*Positive*	ND	ND	*Positive*	*Positive*	ND	ND	ND
V-CC-P	1	ND	ND	ND	*Positive*	*Positive*	ND	ND	ND	ND	ND	ND	ND
V-CC-P	2	ND	ND	ND	*Positive*	*Positive*	ND	ND	ND	ND	ND	ND	ND
V-CC-P	3	ND	ND	ND	*Positive*	*Positive*	ND	ND	ND	ND	ND	ND	ND
V-CC-P	4	ND	ND	ND	*Positive*	*Positive*	ND	ND	ND	ND	ND	ND	ND
V-CC	1	ND	ND	ND	ND	*Positive*	*Positive*	ND	ND	ND	ND	ND	ND
V-CC	2	ND	ND	ND	*Positive*	*Positive*	ND	ND	ND	ND	ND	ND	ND
V-CC	3	ND	ND	ND	*Positive*	*Positive*	ND	ND	*Positive*	*Positive*	ND	ND	ND
V-CC	4	ND	*Positive*	*Positive*	*Positive*	*Positive*	ND	ND	*Positive*	*Positive*	ND	ND	ND

Table 11. Feed conversion (FCR) and average daily gain (ADG) for chickens integrated in the summer and fall for 2017, 2018, 2019

	2017		2018		2019	
	*FCR	†ADG	FCR	ADG	FCR	ADG
Rotation						
V-P-CC	2.78	0.07	2.43	0.09	2.87	0.07
V-CC-P	3.25	0.08	2.73	0.08	2.95	-

*Calculated using the average feed consumed over the average final live weight. † Calculated based on total weight gained from the first day on the plot divided by the number of days on the plot. 2017= were red ranger chickens (Welp hatchery, Bancroft IA) and 2018 and 2019 = Imperial (Moyer's Chicks, Quakertown, PA.