

1 Appendix I

2 In 2017 Broccoli (*Brassica oleraceae* var. Italica cv. Belstar, Seedway Hall, NY) was planted to  
3 all rotations on 17, April 2017. For V-P-CC integration of red ranger chicken (RRC) (Welp  
4 Hatchery Bancroft, IA) followed broccoli harvest and a cover crop of cereal rye (*Secale cereal*,  
5 cv *Variety not stated*, Albert Lea Seed, Albert Lea MN) was planted chicken removal. V-CC-P  
6 and V-CC rotations were planted to a cover crop mixture of crimson clover (*Trifolium*  
7 *incanatum*)(Green Cover Seed, Bladen, NE) and oats (*Avena sativa*, Albert Lea Seeds, Albert  
8 Lea, MN) after broccoli harvest and RRC were integrated into the cover crop after establishment  
9 for V-CC-P and romaine lettuce *Lactuca sativa* cv. Holon (Johnny's Seeds, Winslow, ME) was  
10 planted in V-CC. Rotations for 2018 and 2019 followed the same patterns as for 2017 except for  
11 changes in the vegetable crops grown.

12 In 2018 the crops were romaine lettuce and bell pepper. Romaine lettuce (*Lactuca sativa* cv  
13 Coastal star, Paris Island, Greene towers, Jericho, Freckles) was planted on 24, April 2018 in V-  
14 P-CC and V-CC-P rotations spinach (*Spinacea oleracea* cv Corvair, Acadia (Johnny's Seeds,  
15 Winslow, ME), Regiment, Butterflay, Renegade (High Mowing Organic Seeds, Walcott, VT).  
16 was planted on 16, April 2019 in all three rotations. The lettuce and spinach were part of an  
17 organic lettuce cultivar trial not presented here). Pepper (*Capsicum annum* cv. Milena, King of  
18 the north, Golden California wonder, California wonder, Sweet chocolate) on 16, May 2018, and  
19 Carrots (*Daucus carota* cv Miami, Nantes fancy Napoli, Negovia, Yaya) was planted on 7  
20 August 2019 in V-CC rotations. Imperial chickens (IC) (Moyer's, Quakertown, PA) were used in  
21 place of RRC in V-P-CC and V-CC-P.

22 **Year one:** Transplant production was carried out in the Department of Horticulture greenhouses  
23 at Iowa State University, Ames, IA. On 3, March spring of 2017 broccoli was sown into 72 cell

24 trays using an organic potting mix (Beautiful Land Products, West Branch, IA). After emergence  
25 broccoli plants were thinned to one seedling per cell. Broccoli transplants were fertilized as  
26 needed using an organic 2-4-1 liquid fertilizer derived from hydrolyzed fish (Neptune's Harvest  
27 organic fertilizer, Gloucester, MA) Broccoli transplants were grown for 6 weeks. Six-week-old  
28 broccoli transplants hand planted on the 17, April 2017 at the Horticulture Research Station into  
29 4.5 x 7.5-meter plots. Plots were set up with 5 beds each. Bed length was 7.5 meters long with  
30 30cm between plants and 1m between beds. After planting broccoli was fertilized with 2-4-1  
31 every other week through a fertilizer injector (Dosatron, Clearwater, Florida) to provide plants  
32 with sufficient nutrition throughout the season. Plants were monitored and sprayed as needed  
33 with DiPel Pro (Valent BioSciences Corp., Osage, IA) (*Bacillus thuringiensis v kurstaki*) to  
34 protect against cabbage looper (*Trichoplusia ni*) and imported cabbageworm (*Pieris rapae*). June  
35 was unseasonably warm and broccoli did not perform well. Broccoli was harvested on 1<sup>st</sup> July  
36 2017 by cutting broccoli heads at the stem to leave a 3.5-10cm stalk. All broccoli was deemed as  
37 unmarketable due to insufficient head size or discoloration. After completion of harvest, On 1  
38 July 2017 an electric fence was erected around the perimeter of the field in an effort to protect  
39 chickens from predators. On 10, July 2017 chickens were placed on V-P-CC plots. Chickens  
40 were 37 days old. Due to mortalities during brooding only 38 of 40 chicks were available for the  
41 study. Chickens were housed in 1.5. x 1.2m floorless movable coops to allow them to forage on  
42 broccoli residue. One pen per replication was used. Ten birds were placed in rep 1 and 4, 9 were  
43 placed in rep 2 and 3. Chickens remained on V-P-CC plots for nine weeks and were removed on  
44 30, August 2017. After chicken removal plots were tilled and cereal rye (*Secale cereal, cv*  
45 *Variety not stated*, Albert Lea Seed, Albert Lea MN) was hand broadcast seeded at 112kg ha<sup>-1</sup>

46 On 11, July 2017, V-CC-P and V-CC plots the V-CC plots were tilled to incorporate broccoli  
47 residue. Oats (*Avena sativa*, Albert Lea Seeds, Albert Lea, MN) and crimson clover *Trifolium*  
48 *incanatum* (Green Cover Seed, Bladen, NE) were seeded at a rate of 112 and 33.5kg ha-  
49 1 respectively by broadcasting by hand and lightly raking to incorporate Overhead sprinkler  
50 irrigation was used. On 12, September 2017 crimson clover and oat biomass was collected from  
51 V-CC plots by placing a 25x25cm quadrat four times randomly throughout the plot and cutting  
52 all above-ground growth within the quadrat. Biomass was placed in a 67 °C oven to dry down to  
53 a constant weight. On 15, September 2017 RRC was placed on the cover crop in V-CC-P plots  
54 where they remained for 10 weeks and were removed on 8, November 2017.

55 On 17, August 2017 romaine lettuce *Lactuca sativa* cv. Holon (Johnny's Seeds, Winslow, ME)  
56 was seeded in 72 cell flats using the same materials and methods as previously mentioned for  
57 broccoli transplants. On 13, September 2017 V-CC plots were tilled, fertilizer was hand  
58 broadcasted and incorporated. Lettuce was transplanted into beds of double rows 5 rows per plot.  
59 And plants were spaced 30cm apart in all directions with plants in the opposite row staggered.  
60 Lettuce heads were harvested on 9, November 2017. Lettuce did not reach marketable size but  
61 was graded for quality (data not presented).

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63 **Year 2:** On 8 and 16 March, five cultivars of organic romaine lettuce Freckles, Green Towers  
64 (High Mowing Organic Seeds, Walcott, VT), Jericho, Coastal star, and Paris Island (Johnny's).  
65 and pepper (Sweet Chocolate, Milena, King of the North, California Wonder, and Golden  
66 California Wonder) were seeded in 72 and 288 cell trays using an organic medium (Beautiful  
67 land products, West Branch, IA) in the Department of Horticulture greenhouses (pepper  
68 seedlings were later repotted into 50 cell flats).

69 On 19, April 2018 rye biomass from V-P-CC plots was collected. Rye biomass was dried  
70 weighed and ground to 1mm using a Thomas Wiley Laboratory Mill (Thomas Scientific,  
71 Philadelphia PA) The biomass from all four replications was combined to form one composite  
72 sample, which was sent to Ward Laboratories (Kearney, NE) for analysis of total C and N. On 24  
73 April 2018 in treatments V-P-CC and V-CC-P, N was applied using 4-6-4 (Sustane Natural  
74 Fertilizer Inc. Cannon Falls, MN) and plots were tilled, and lettuce was transplanted. Each plot  
75 consisted of five beds, each with two rows of lettuce spaced 1m apart (center-to-center) on bare  
76 ground. The crop was irrigated using drip irrigation and hand weeded as needed throughout the  
77 growing season. Lettuce harvest began on 29 May 2018 and continued once a week until 14 June  
78 2018. Lettuce was counted and graded for marketable yield based on number and weight bolted  
79 heads, number, and weight of heads with tip burn. Head length and head diameter were recorded  
80 by pulling five marketable heads from each treatment and measuring from the top of the head to  
81 the cut end and by taking two measurements at the widest point of the head. On 28 June 2018, 3-  
82 week old imperial chickens were introduced into V-P-CC plots using methods from 2017. V-P-  
83 CC coops housed 10, 8, 9, and 9 birds, respectively. Chickens were removed on 8, August 2018  
84 and fall cover crop of cereal rye was broadcasted. After lettuce harvest, V-P-CC treatments were  
85 treated the same as in 2017. Chickens were integrated into the standing cover crop mixture of  
86 oats and crimson clover on 7 September 2018 and removed on 20, October 2018. V-CC-P coops  
87 had 10, 11, 10, and 10 birds, respectively.

88 Peppers were transplanted into V-CC plots on 16 May 2018 in single rows, which were 1m.  
89 apart. Spacing between plants within a row was 46cm between plants. Three days after  
90 transplanting crimson clover (134kg ha<sup>-1</sup>) was seeded between rows of peppers and mowed  
91 regularly to suppress weeds. Peppers were irrigated through drip irrigation and weeded (within

92 the row) and scouted regularly following recommended organic production practices. Peppers  
93 were harvested weekly starting on 17 July 2018 and continued until 26 September 2018. Peppers  
94 were graded for marketability based on the size and presence/absence of abiotic and biotic  
95 disorders (data not presented). Aboveground biomass was collected from the cover crop between  
96 the rows using methods explained previously.

97 **Year 3:**

98 Rye biomass was collected on 15 April 2019 using methods previously described. Preplant  
99 fertilizer was applied using 4-6-4 (Sustane Natural Fertilizer Inc. Cannon Falls, MN) and plots  
100 were tilled. Spinach was direct seeded using a Jang seeder (Jang Automation Co., Ltd. Beobwon-  
101 ro, Songpa-gu, Seoul, Korea). Beds had four rows spaced 15 cm apart. The crop was irrigated  
102 using drip irrigation and hand weeded as needed throughout the growing season

103 Spinach harvest started 29, May 2019 followed by harvests on 6, June and 11, June 2019 by  
104 harvesting a 1.5m section of one center row of each of the five beds. Total and marketable yield  
105 of spinach was recorded along with the dry weight of spinach. Spinach was deemed  
106 unmarketable if it was yellowing or starting to bolt. Most spinach graded as unmarketable was  
107 placed in the bolting or yellowing category in the final harvest. Dry weight was recorded by  
108 drying down all marketable spinach from 1.5m section was dried to constant weight at 67°C and  
109 weighed for determination of dry weight.

110 On 11 June 2019 4-week old imperial chickens were introduced into V-P-CC plots using  
111 methods from 2017. V-P-CC coops housed 10 birds in each replication. Chickens were removed  
112 on 18, July 2019 and fall cover crop of cereal rye was broadcasted. After spinach harvest V-CC-  
113 P and V-CC treatments were treated the same as in 2017. Oats and crimson clover did not

114 establish well in 2019 and it was reseeded with buckwheat on 7 August 2019. Chickens were  
115 integrated into the standing cover crop mixture of buckwheat on 6 September 2019 and removed  
116 on 31 October 2019. In V-CC plots carrots were direct seeded after the destruction of the  
117 summer cover crop. Carrots were planted on 7 August 2019 using the same methods as for  
118 spinach. All rows of carrots were harvested on 30 October 2019. Carrots tops were removed and  
119 then graded based on marketability. Carrots were deemed unmarketable if they fell into the  
120 categories of forked, cracked, damaged by rodents, or small. Five marketable carrots were pulled  
121 to determine the average length and shoulder diameter. The same five carrots were set aside and  
122 sliced put through a juicer and the juice analyzed for brix. The juice was filtered through  
123 cheesecloth and three readings were collected and averaged.

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