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Recto: Martin SAMPHIRE et al. Biodegradable plastic film mulch does not affect soil organic matter content.
RESEARCH ARTICLE

Use of biodegradable plastic film mulch over three years of organic horticultural production promotes yield but does not affect soil organic matter content

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SUPPLEMENTARY MATERIALS

1 Methods for determining initial soil chemical and physical properties

Initial values for soil pH, P, K and Mg content were determined by NRM Laboratories, Cawood Scientific, Berkshire, UK (n = 5). Olsen P content was determined by extraction with sodium bicarbonate [1], and extractable K and Mg were determined by extraction with ammonium nitrate[2]. SOM and C/N ratio were determined as described in the main manuscript (n = 10), and bulk density was determined by weighing oven-dried (105 °C, 16 h) samples of soil taken with a stainless steel corer (100 mm internal diameter) (n = 3) (Table S1).

References

1. Olsen S.R., Sommers E.L. Phosphorus soluble in sodium bicarbonate. Methods of Soil Analysis: Part 2. Madison, WI: *American Society of Agronomy*, 1982, 404–430
2. Thomas G.W. Exchangeable cations. Methods of Soil Analysis: Part 2. Madison, WI: *American Society of Agronomy*, 1982, 159–165

2 Figures

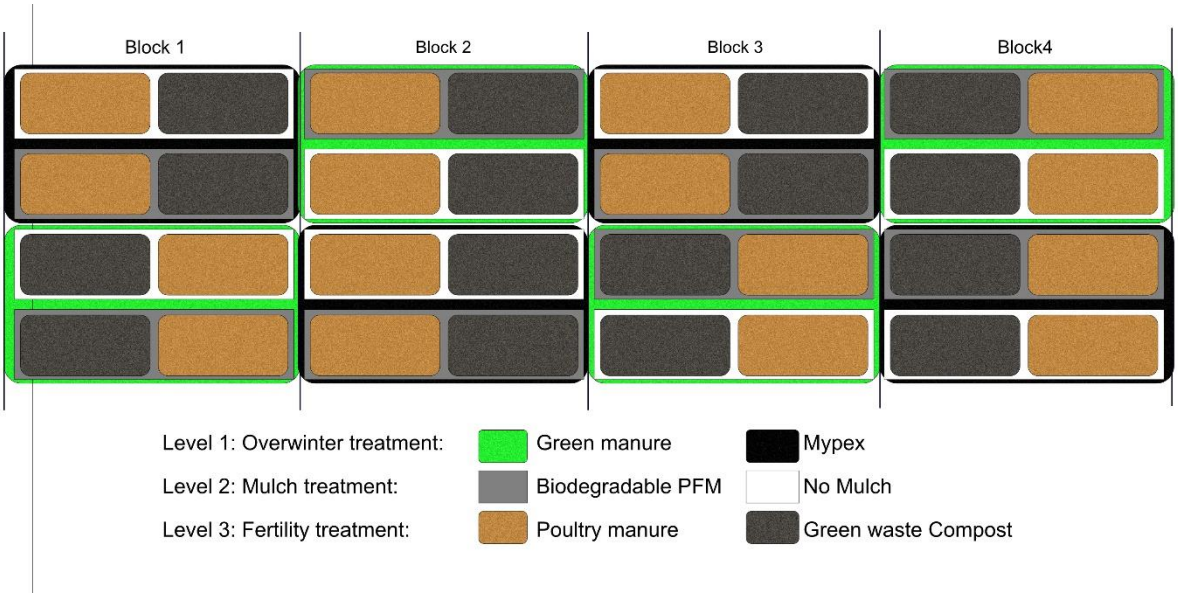

Fig. S1 The layout of plots and treatments used in the study. The 4 beds running west to east were divided into 4 blocks. Each block was split into two over-winter treatments, which occupied adjacent two beds; these were split into two plots, which occupied a single block in each bed containing the mulch treatments; these were split into two sub-pots containing the fertility treatments, so each block contained all combinations of the three treatments. Beds were 1.2 m wide with 0.3 m wheelings between them, and blocks were 4.8 m long.

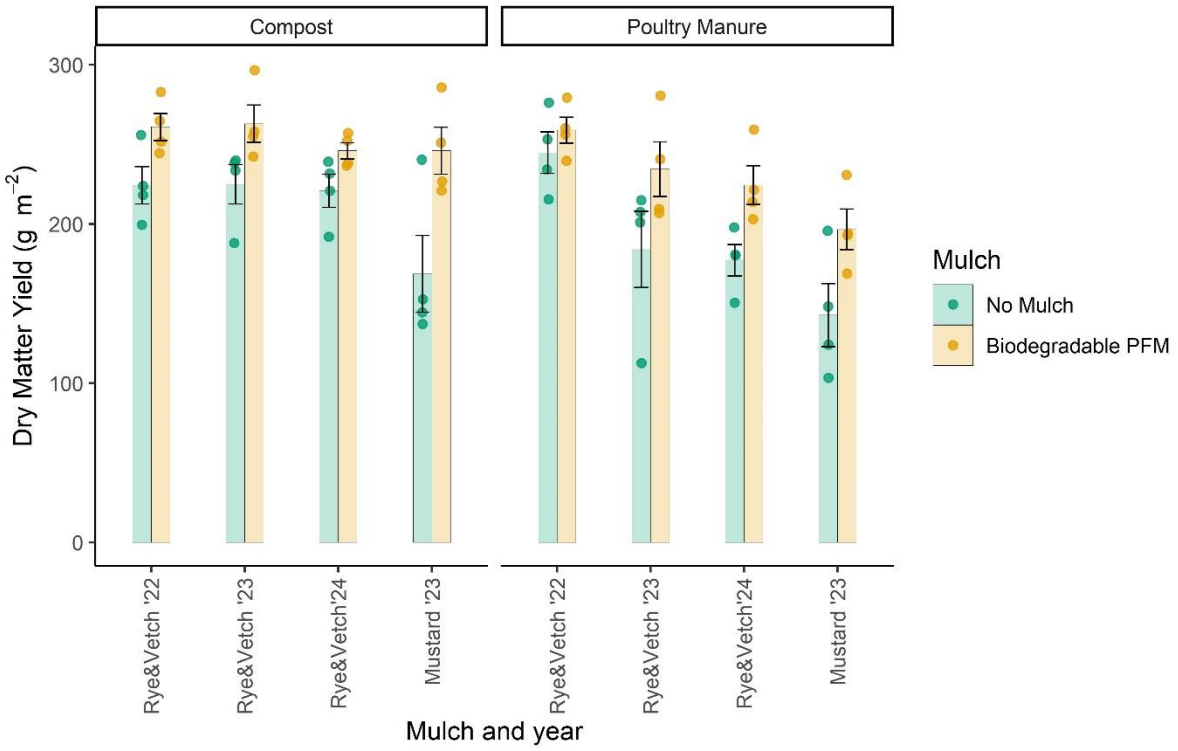

Fig. S2 Dry matter yield per m^2 for the green manure in the different years of the experiment in plots with or without biodegradable PFM and amended with green waste compost or poultry manure. Values represent means ± SEM, and dots represent individual data points (n = 4).

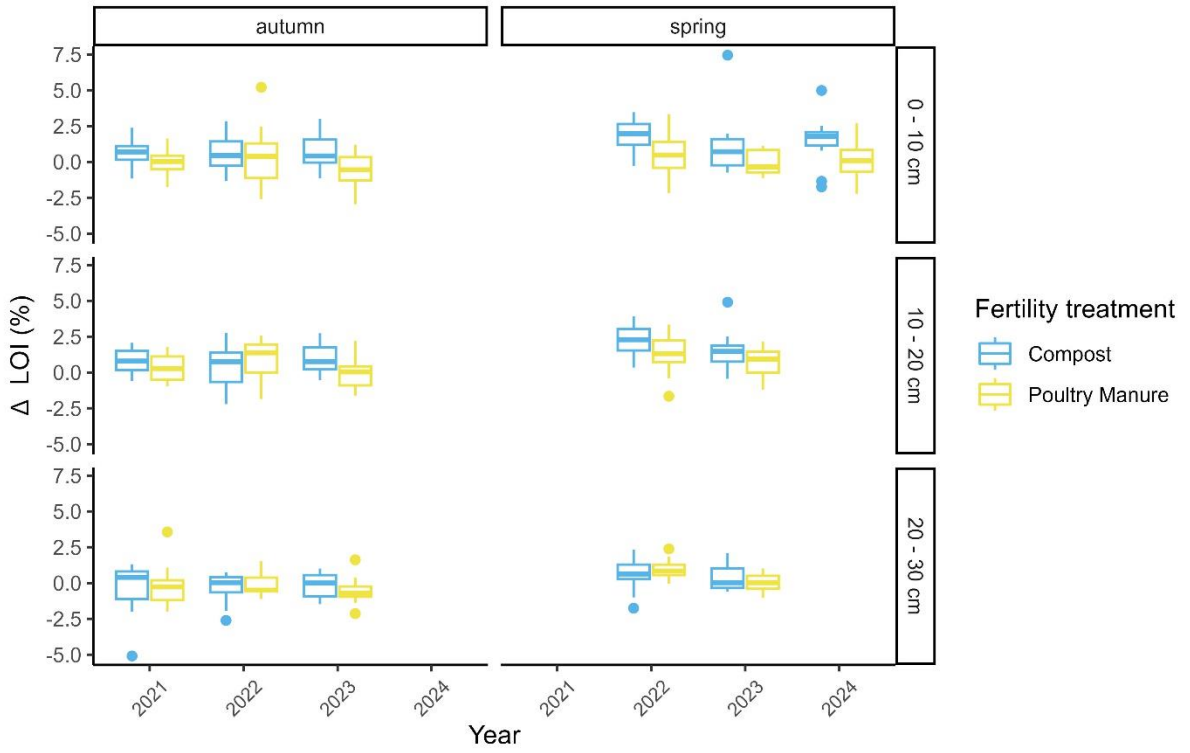

Fig. S3 Changes in soil SOM (LOI) over three years of vegetable production with green waste compost and poultry manure. The Centre line is the mean value; the lower and upper lines are the first and third quantile; and the whiskers represent 1.5 times the interquartile range (n = 16).

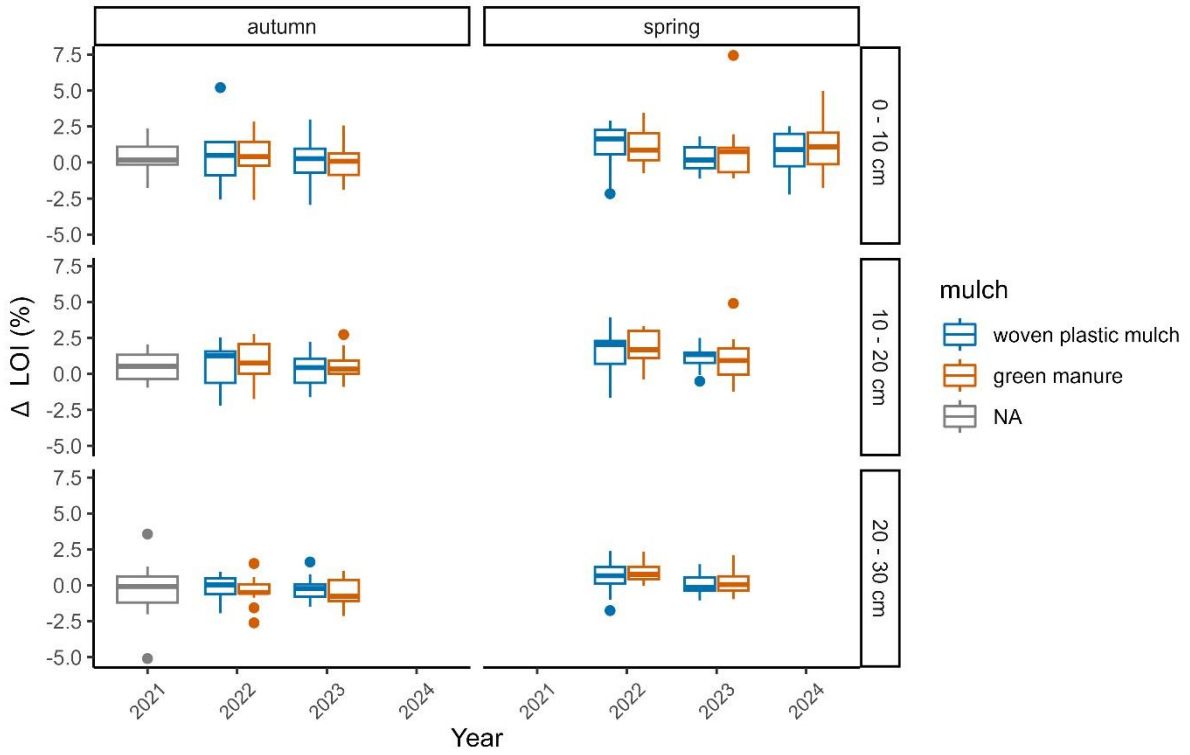

Fig. S4 Changes in soil SOM (LOI) over three years of vegetable production with overwinter green manure of rye and vetch or overwinter mulching with a woven polypropylene much. The centre line is the mean value; the lower and upper lines are the first and third quantile; and the whiskers represent 1.5 times the interquartile range (n = 16).

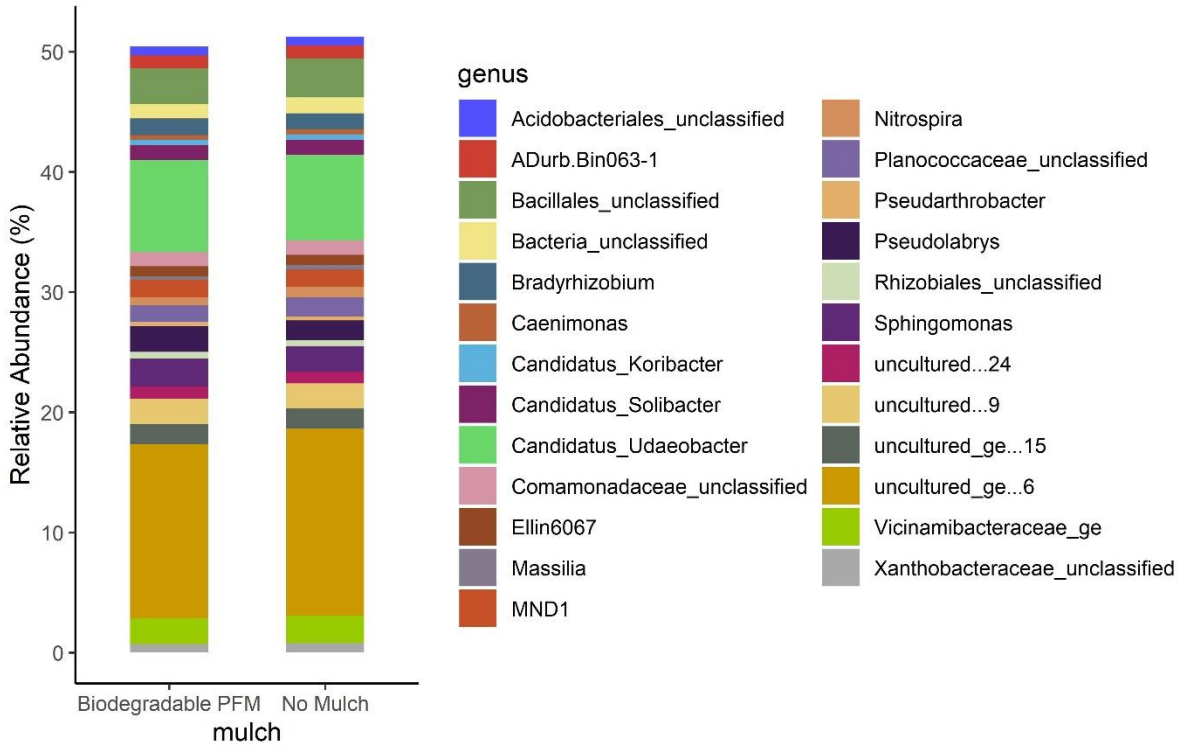

Fig. S5 Relative abundance of the 25 most abundant OTUs by bacterial genus in soil from plots with and without biodegradable PFM. 10th August, year 2 of the experiment (n = 16).

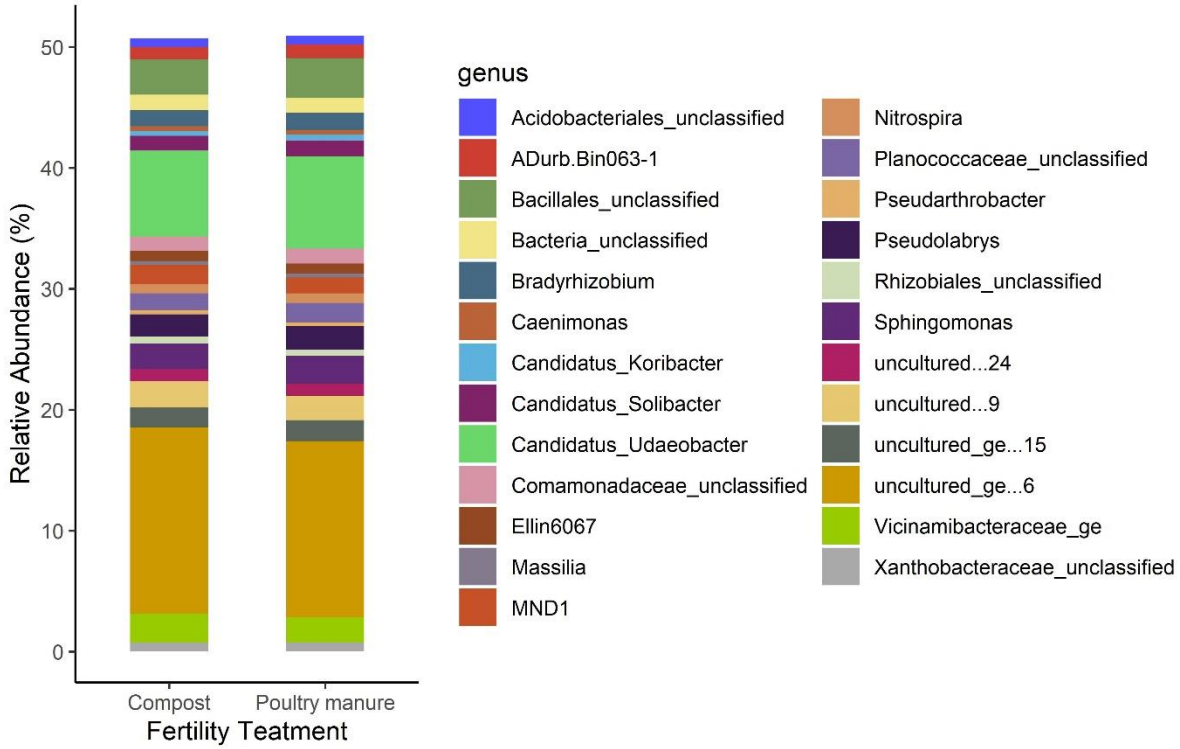

Fig. S6 Relative abundance of the 25 most abundant OTUs by bacterial genus in soil from plots amended with green waste compost or poultry manure. 10th August, year 2 of the experiment (n = 16).

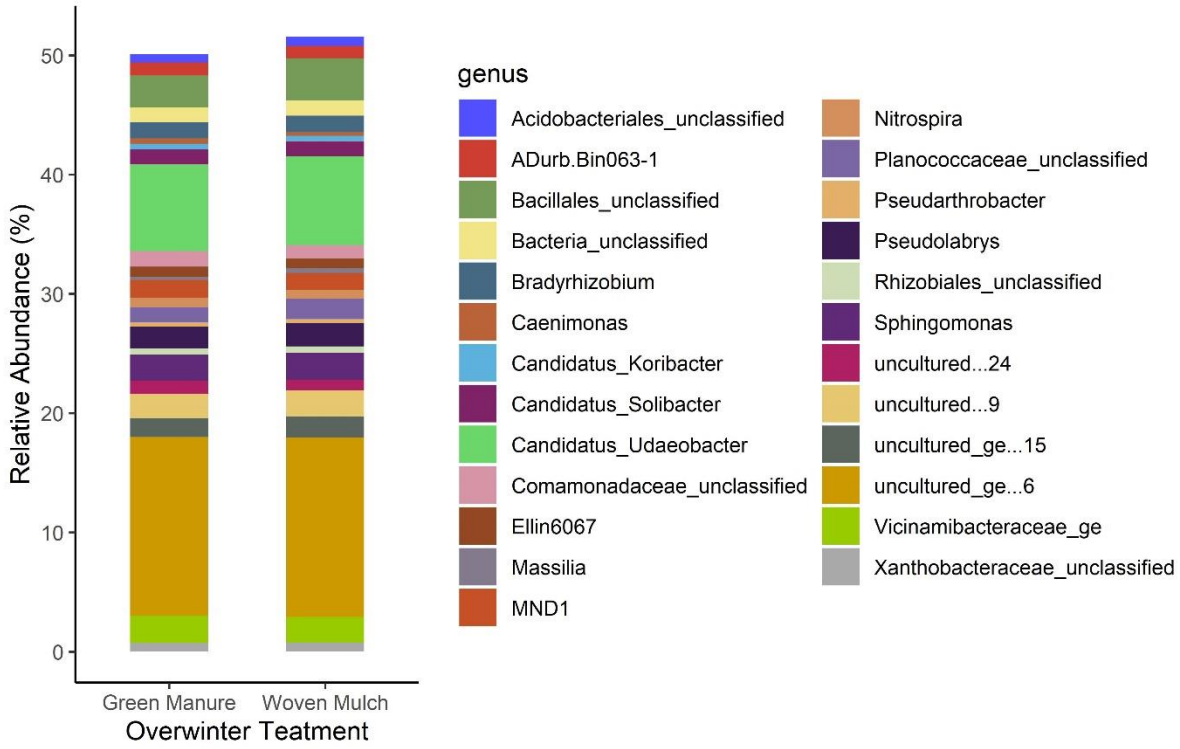

Fig. S7 Relative abundance of the 25 most abundant OTUs by bacterial genus in soil from plots following an overwinter green manure of rye and vetch or overwinter mulching with a woven polypropylene mulch. 10th August, year 2 of the experiment (*n* = 16).

3 Tables

Table S1 Topsoil properties (0–10 cm) at the experimental site

Value	pH	P (mg·kg^{-1})	K (mg·kg^{-1})	Mg (mg·kg^{-1})	Total C (g·kg^{-1})	C:N ratio	Bulk density (g·cm^{-3})
n	5	5	5	5	10	10	3
Means ± SEM	6.0 ± 0.04	16.9 ± 1.5	127.4 ± 10.6	88.2 ± 1.7	61 ± 1.2	13.8 ± 0.27	1.06 ± 0.02

Note: Values represent means ± SEM. Data expressed on a dry weight basis.

Table S2 Nutrient content of organic amendments and nutrient application rates via these amendments

Value	Green Waste Compost	Applied (g·m^{-2})	Poultry manure	Applied (g·m^{-2})
Oven dry matter (%)	40.2 ± 0.5		92.3 ± 0.1	
Total N (% w/w)	1.68 ± 0.02	16.9	4.44 ± 0.08	4.1
Total P (% w/w)	0.28 ± 0.00	2.8	1.32 ± 0.02	1.2
Total K (% w/w)	0.82 ± 0.01	8.2	2.39 ± 0.03	2.2
Total Mg (% w/w)	0.36 ± 0.01	3.6	0.75 ± 0.01	0.7

Note: Values represent means ± SEM (*n* = 5). Nutrient content data expressed on a dry weight basis.

Table S3 Details of crops and green manures grown during the experiment

Season	Growing season 2021	Over-winter 2021–2022	Growing season 2022	Over-winter 2022–2023	Growing season 2023	Post-harvest 2023	Over-winter 2023–2024
Crop	Leeks	Cereal Rye and Vetch*	Sweetcorn	Cereal Rye and Vetch*	Lettuce	Mustard*	Cereal Rye and Vetch*
	Allium ampeloprasum L.cv. Jolant	*Secale cereale* L. cv. Elias, *Vicia sativa* L. cv. Caravelle	*Zea mays* convar. *saccharata* var. *rugosa* cv.Goldcrest	*Secale cereale* L. cv. Elias, *Vicia sativa* L. cv. Caravelle	*Lactuca sativa* L. cv. Frostex	Sinapis alba L.	*Secale cereale* L. cv. Elias, *Vicia sativa* L. cv. Caravelle
Planting/sowing density	10 plants m^{-2}	25 $g \cdot m^{-2}$	6.25 plants m^{-2}	25 $g \cdot m^{-2}$	10 plants m^{-2}	10 $g \cdot m^{-2}$	25 $g \cdot m^{-2}$
Date planted	25/5/2021	5/10/2021	23/5/2022	10/10/2023	19/5/2023	27/7/2023	11/9/2023
Date harvest/destroyed	14/9/2021	18/4/2021	17/9/2022	10/4/2024	24/7/2023	8/9/2023	

Note: *Green manures were grown only on half of the plots, with the other half covered with woven plastic mulch as a control. Rye and Vetch were incorporated in the top 5 cm on destruction in 2022 and 2023; the mustard was removed.

Table S4 Carbon inputs over the course of the experiment

Season input was incorporated into the soil			Spring Year 1	Autumn Year 1		Spring Year 2		Autumn Year 2		Spring Year 3		Autumn Year 3		Spring Year 4*
Mulch	Fertility treatment	Overwinter treatment	Fertility input ($g \cdot m^{-2}$ C)	Mulch film ($g \cdot m^{-2}$ C)	Crop residue ($g \cdot m^{-2}$ C)	Green manure ($g \cdot m^{-2}$ C)	Fertility input ($g \cdot m^{-2}$ C)	Mulch film ($g \cdot m^{-2}$ C)	Crop residue ($g \cdot m^{-2}$ C)	Green manure ($g \cdot m^{-2}$ C)	Fertility input ($g \cdot m^{-2}$ C)	Mulch film ($g \cdot m^{-2}$ C)	Crop residue ($g \cdot m^{-2}$ C)	Green manure ($\cdot m^{-2}$ C)
No Mulch	Compost	No green manure	432	0	39	0	432	0	594	0	432	0	0	0
		Green manure	432	0	39	102	432	0	753	105	432	0	0	107
	Manure	No green manure	39	0	44	0	39	0	510	0	39	0	0	0
		Green manure	39	0	44	115	39	0	407	88	39	0	0	84
PFM	Compost	No green manure	432	9	45	0	432	9	964	0	432	9	0	0
		Green manure	432	9	45	123	432	9	852	120	432	9	0	116
	Manure	No green manure	39	9	64	0	39	9	1086	0	39	9	0	0
		Green manure	39	9	64	121	39	9	1146	110	39	9	0	107

Note: *The green manure in the final year of the experiment was incorporated after the final experimental measurements were collected.

Table S5 Yield of crops during the experiment

Mulch	Fertiliser	Green manure/Overwinter treatment	2021 (leeks)		2022 (sweetcorn)		2023 (lettuce)	
			Economic yield ($Mg \cdot ha^{-1}$)	Dry matter (g per plant)	Economic yield (cobs) ($Mg \cdot ha^{-1}$)	Dry matter (whole plant) (g per plant)	Economic yield ($Mg \cdot ha^{-1}$)	Dry matter yield (g per plant)
			$n = 8$	$n = 8$	$n = 4$	$n = 4$	$n = 4$	$n = 4$
No mulch	Compost	No green manure	17.8 ± 1.22	32.0 ± 2.45	1.48 ± 0.16	309.9 ± 49.0	19.58 ± 1.27	15.36 ± 1.15
		Green manure			1.82 ± 0.10	373.8 ± 37.0	23.89 ± 0.85	18.36 ± 0.39
	Poultry manure	No green manure	22.1 ± 1.22	38.0 ± 2.12	1.43 ± 0.11	276.5 ± 6.7	16.96 ± 2.42	12.43 ± 2.01
		Green manure			1.42 ± 0.06	232.5 ± 19.2	18.19 ± 1.41	14.48 ± 0.91
Biodegradable PFM	Compost	No green manure	28.5 ± 1.49	46.5 ± 2.57	2.54 ± 0.15	497.5 ± 39.0	28.53 ± 1.93	22.10 ± 1.45
		Green Manure			2.48 ± 0.19	483.9 ± 58.9	31.91 ± 0.91	24.17 ± 0.65
	Poultry manure	No Green Manure	30.4 ± 0.74	52.8 ± 3.06	2.45 ± 0.16	536.0 ± 84.8	25.54 ± 2.52	19.41 ± 2.08
		Green Manure			2.96 ± 0.19	607.0 ± 12.5	24.99 ± 1.76	18.89 ± 1.18
Statistical analysis (significance of factor in mixed effects model)								
Mulch			***	***	***	**	***	***
Fertiliser			*	*	ns	0.056	**	**
Green Manure			NA	NA	ns	ns	*	*
Mulch*Fertiliser			ns	ns	0.061	*	ns	ns
Mulch*Green manure			NA	NA	ns	ns	ns	ns
Green manure*Fertiliser			NA	NA	ns	ns	ns	ns
Mulch*Green Manure*Fertiliser			NA	NA	ns	ns	ns	ns

Note: Values represent means ± SEM. ns, not significant; NA, not available. Significant differences: * $p < 0.05$, ** $p < 0.005$, *** $p < 0.001$. Economic yield means the yield of the saleable part of the plant trimmed and prepared to the standard of the farm on which the experiment was conducted. All residues were incorporated into the soil post-harvest, and the economic product was removed.

Table S6 C/N ratios of crop and green manure biomass

Mulch	Fertiliser	Green manure/Overwinter treatment	2021 (leeks)	2022 (sweetcorn)	2023 (lettuce)	2022 (rye and vetch)	2023 (rye and vetch)	2024 (rye and vetch)	2023 (mustard)
			n = 4	*n* = 4	*n* = 4	*n* = 4	*n* = 4	*n* = 4	*n* = 4
No Mulch	Compost	No Green Manure	11.3 ± 0.8	45.4 ± 4.6	9.69 ± 0.26				
		Green Manure		41.7 ± 5.4	9.04 ± 0.33	30.2 ± 1.8	26.7 ± 1.3	26.6 ± 2.1	19.8 ± 0.32
	Poultry Manure	No Green Manure	11.2 ± 0.8	45.0 ± 8.1	9.99 ± 0.92				
		Green Manure		37.0 ± 4.1	9.08 ± 0.20	30.0 ± 1.7	28.5 ± 2.8	34.3 ± 1.45	23.9 ± 0.63
Biodegradable PFM	Compost	No Green Manure	11.3 ± 1.1	50.1 ± 7.0	9.57 ± 0.60				
		Green Manure		43.4 ± 6.5	8.36 ± 0.22	27.2 ± 0.3	27.5 ± 0.8	25.7 ± 2.2	23.5 ± 2.30
	Poultry Manure	No Green Manure	11.4 ± 0.4	56.9 ± 11.3	8.79 ± 0.79				
		Green Manure		47.2 ± 5.7	9.14 ± 0.37	29.7 ± 4.9	32.4 ± 1.75	34.5 ± 0.40	26.4 ± 1.56
Statistical analysis (significance of factor in mixed effects model)									
Mulch			ns	*	ns	*	ns	ns	**
Fertiliser			ns	ns	ns	ns	*	*	*
Green Manure			NA	*	*	ns	NA	NA	NA
Mulch*Fertiliser			ns	0.061	ns	ns	ns	ns	ns
Mulch*Green manure			NA	ns	ns	ns	NA	NA	NA
Green manure*Fertiliser			NA	ns	ns	ns	NA	NA	NA
Mulch*Green Manure*Fertiliser			NA	ns	ns	ns	NA	NA	NA

Note: Values represent means ± SEM. ns, not significant; NA, not available. Significant differences: * $p < 0.05$, ** $p < 0.005$, *** $p < 0.001$.

Table S7 Tea Bag Index (TBI) rate of decay, *k*, and stabilisation factor, *S*, with or without a biodegradable PFM, fertilised with green-waste compost (2.5 kg·m^{-2}) or poultry manure (100 g·m^{-2}), and soil with or without green-manure of cereal rye and vetch or woven polypropylene mulch in the overwinter period

Mulch	Fertiliser	Green manure/Overwinter treatment TBI factor	2021		2022		2023	
			k	S	*k*	S	*k*	S
			n = 8	*n* = 8	*n* = 4	*n* = 4	*n* = 4	*n* = 4
No mulch	Compost	No green manure	0.028 ± 0.006	0.195 ± 0.008	0.021 ± 0.002	0.263 ± 0.012	0.021 ± 0.002	0.237 ± 0.008
		Green manure			0.019 ± 0.002	0.265 ± 0.003	0.020 ± 0.001	0.218 ± 0.019
	Poultry manure	No green manure	0.027 ± 0.002	0.209 ± 0.005	0.022 ± 0.002	0.278 ± 0.006	0.022 ± 0.002	0.226 ± 0.017
		Green manure			0.016 ± 0.001	0.282 ± 0.007	0.020 ± 0.001	0.253 ± 0.015
Biodegradable PFM	Compost	No green manure	0.033 ± 0.005	0.177 ± 0.008	0.021 ± 0.002	0.230 ± 0.012	0.021 ± 0.001	0.225 ± 0.012
		Green manure			0.017 ± 0.001	0.200 ± 0.005	0.024 ± 0.002	0.258 ± 0.011
	Poultry manure	No green manure	0.030 ± 0.002	0.188 ± 0.005	0.019 ± 0.000	0.212 ± 0.009	0.023 ± 0.001	0.243 ± 0.013
		Green manure			0.019 ± 0.002	0.203 ± 0.014	0.021 ± 0.002	0.273 ± 0.023
	Statistical analysis (significance of factor in mixed effects model)							
Mulch			ns	***	ns	***	ns	ns
Fertiliser			ns	ns	ns	ns	ns	ns
Green manure			NA	NA	**	ns	ns	ns
Mulch*Fertiliser			ns	ns	ns	ns	ns	ns
Mulch*Green manure			NA	NA	ns	ns	ns	ns
Green manure*Fertiliser			NA	NA	ns	ns	ns	ns
Mulch*Green Manure*Fertiliser			NA	NA	ns	ns	ns	ns

Note: Values represent means ± SEM. ns, not significant; NA, not available. Significant differences: * $p < 0.05$, ** $p < 0.005$, *** $p < 0.001$.

Table S8 SOM content at different depths after 2 or 3 years of horticultural rotation with or without biodegradable PFM, amended with green waste compost or poultry manure, and with an overwinter green manure of rye and vetch or overwinter mulching with a woven polypropylene mulch.

Mulch	Fertiliser	Overwinter treatment	0–10 cm			10–20 cm		20–30 cm	
			2023		2024	2023		2023	
			Spring	Autumn	Spring	Spring	Autumn	Spring	Autumn
			SOM (%)	SOM (%)	SOM (%)	SOM (%)	SOM (%)	SOM (%)	SOM (%)
No mulch	Compost	No green manure	13.00 ± 0.33	13.34 ± 0.33	14.35 ± 0.26	12.53 ± 0.11	12.17 ± 0.31	10.19 ± 0.26	10.05 ± 0.36
		Green manure	13.55 ± 0.34	12.87 ± 0.46	14.13 ± 0.92	13.09 ± 0.81	12.10 ± 0.31	10.12 ± 0.24	9.96 ± 0.36
	Poultry manure	No green manure	12.33 ± 0.31	11.92 ± 0.41	11.80 ± 0.38	12.02 ± 0.21	11.09 ± 0.27	9.82 ± 0.23	9.42 ± 0.07
		Green manure	12.44 ± 0.35	11.85 ± 0.40	12.81 ± 0.47	11.78 ± 0.47	11.42 ± 0.30	10.32 ± 0.30	9.08 ± 0.37
Biodegradable PFM	Compost	No green manure	13.29 ± 0.38	13.18 ± 0.62	14.41 ± 0.11	12.83 ± 0.39	12.40 ± 0.42	10.60 ± 0.38	9.72 ± 0.21
		Green manure	14.49 ± 1.34	13.58 ± 0.42	13.39 ± 0.65	12.51 ± 0.41	12.39 ± 0.41	10.82 ± 0.34	10.05 ± 0.37
	Poultry manure	No green manure	12.69 ± 0.39	12.02 ± 0.63	12.32 ± 0.44	12.27 ± 0.34	11.28 ± 0.62	10.35 ± 0.11	10.26 ± 0.39
		Green manure	12.58 ± 0.32	12.15 ± 0.23	13.75 ± 0.47	12.15 ± 0.36	11.40 ± 0.32	9.94 ± 0.17	9.32 ± 0.16
Statistical analysis (significance of factor in mixed effects model)									
Mulch			ns	ns	ns	ns	ns	ns	ns
Fertiliser			*	***	***	*	*	ns	0.085
Green Manure			ns	ns	ns	ns	ns	ns	ns
Mulch*Fertiliser			ns	ns	ns	ns	ns	ns	ns
Mulch*Green manure			ns	ns	ns	ns	ns	ns	ns
Green manure*Fertiliser			ns	ns	*	ns	ns	ns	ns
Mulch*Green Manure*Fertiliser			ns	ns	ns	ns	ns	ns	ns

Note: Values represent means ± SEM ($n = 4$). ns, not significant. Significant differences: * $p < 0.05$, ** $p < 0.005$, *** $p < 0.001$.