

Combining targeted grass traits with red clover improves grassland performance and reduces need for nitrogen fertilisation

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1 Supplementary Information

2 **Table S1.** Herbage cut dates and ammonium nitrate fertiliser application rates and dates at
 3 the two experimental sites.

Nitrogen fertiliser application rates							
Sward composition	Annual N rate (kg N ha ⁻¹)	First application (kg N ha ⁻¹)	Second application (kg N ha ⁻¹)	Third application (kg N ha ⁻¹)			
	0	-	-	-			
Single species swards (F and R)	75	30	26.3	18.8			
	150	60	52.5	37.5			
	300	120	105	75			
	450	180	157.5	112.5			
	600*	240	210	150			
Swards with clover (FC and RC)	0	-	-	-			
	50	50	-	-			
Fertiliser application dates							
	1	2	3	4	5	6	-
Henfaes	22/04/2017	05/06/2017	24/07/2017	20/04/2018	15/06/2018	17/08/2018	-
North Wyke	13/03/2017	19/05/2017	05/07/2017	20/04/2018	08/06/2018	20/07/2019	-
Herbage cut dates							
	1	2	3	4	5	6	7
Henfaes	01/06/2017	17/07/2017	19/09/2017	30/05/2018	09/08/2018	10/10/2018	-
North Wyke	24/04/2017	21/06/2017	09/08/2017	19/10/2017	23/05/2018	10/07/2018	10/09/2018

4 F = *festulolium*, R = ryegrass hybrid, FC = F with red clover, RC = R with red clover

5 *at HF only

6 Dates format: dd/mm/yyyy

7

8 **Table S2.** Dry matter yield and nitrogen offtake for individual herbage cuts for each sward
 9 treatment, at each site and nitrogen application rate. HF = Henfaes experimental site, NW =
 10 North Wyke experimental site, F = *festulolium*, R = ryegrass hybrid, FC = F with red clover, RC
 11 = R with red clover. Values represent means ± standard error (*n* = 4 at HF and 5 at NW).

Site	Sward treatment	Nitrogen rate (kg N ha ⁻¹)	Year	Cut	Dry matter yield (t ha ⁻¹)	Nitrogen offtake (kg N ha ⁻¹)
HF	F	0	2017	1	3.30 ± 0.25	36.8 ± 4.1
				2	2.02 ± 0.62	22.6 ± 8.1

			2018	3	0.58 ± 0.12	9.2 ± 2.1	
				1	1.76 ± 0.16	38.8 ± 5.6	
				2	1.15 ± 0.42	18.1 ± 3.1	
		75	2017	3	0.61 ± 0.19	19.2 ± 5.9	
				1	5.09 ± 0.06	68.0 ± 4.1	
				2	4.13 ± 0.46	50.5 ± 11.3	
			2018	3	1.51 ± 0.19	27.5 ± 4.5	
				1	2.68 ± 0.23	35.2 ± 4.7	
				2	1.43 ± 0.09	21.6 ± 2.2	
		150	2017	3	0.74 ± 0.07	17.4 ± 1.8	
				1	5.53 ± 0.39	80.4 ± 3.8	
				2	5.01 ± 0.09	54.9 ± 3.2	
			2018	3	3.71 ± 0.77	76.9 ± 21.7	
				1	3.72 ± 0.57	67.8 ± 20.5	
				2	1.49 ± 0.31	27.7 ± 5.5	
		300	2017	3	1.41 ± 0.25	34.6 ± 6.5	
				1	5.73 ± 0.19	117.2 ± 10.4	
				2	7.06 ± 0.66	100.9 ± 7.4	
			2018	3	6.65 ± 0.62	183.7 ± 37.1	
				1	5.36 ± 0.31	139.6 ± 16.5	
				2	1.47 ± 0.49	35.7 ± 11.3	
		450	2017	3	2.48 ± 0.20	73.8 ± 8.0	
				1	6.57 ± 0.39	150.0 ± 4.9	
				2	7.00 ± 0.67	114.8 ± 23.9	
			2018	3	7.31 ± 0.74	169.7 ± 16.3	
				1	5.37 ± 0.25	120.1 ± 35.9	
				2	1.15 ± 0.33	24.5 ± 5.1	
		600	2017	3	2.66 ± 0.21	104.4 ± 6.6	
				1	6.94 ± 0.32	196.9 ± 16.3	
				2	7.15 ± 0.65	173.3 ± 19.7	
			2018	3	6.00 ± 0.70	172.4 ± 29.3	
				1	6.15 ± 0.26	158.9 ± 40.6	
				2	1.65 ± 0.22	34.5 ± 4.2	
		FC	0	2017	3	2.23 ± 0.30	92.7 ± 10.8
					1	6.45 ± 0.70	114.4 ± 12.2
					2	10.82 ± 0.34	146.8 ± 13.2
				2018	3	7.82 ± 1.20	123.6 ± 21.7
					1	10.02 ± 0.40	102.6 ± 7.2
					2	5.71 ± 2.18	69.6 ± 23.7
			50	2017	3	4.25 ± 0.99	93.9 ± 28.5
					1	9.43 ± 0.57	177.1 ± 8.8
					2	9.29 ± 0.54	130.4 ± 7.5
2018	3	7.74 ± 0.77	109.6 ± 10.2				
	1	11.31 ± 1.35	142.0 ± 34.8				
	2	4.23 ± 1.72	53.0 ± 21.3				
			3	4.48 ± 0.62	83.9 ± 13.8		

	R	0	2017	1	2.55 ± 0.48	31.6 ± 9.7
				2	0.97 ± 0.23	10.3 ± 2.6
				3	0.60 ± 0.21	12.5 ± 6.1
			2018	1	1.26 ± 0.28	22.0 ± 3.8
				2	0.94 ± 0.18	17.5 ± 4.6
				3	0.53 ± 0.17	16.9 ± 6.2
		75	2017	1	3.91 ± 0.71	46.0 ± 11.3
				2	3.34 ± 0.64	32.4 ± 7.9
				3	1.42 ± 0.30	22.3 ± 6.3
			2018	1	3.19 ± 0.44	68.1 ± 14.6
				2	1.12 ± 0.21	23.1 ± 4.6
				3	1.14 ± 0.05	28.6 ± 1.6
		150	2017	1	4.38 ± 0.63	51.8 ± 8.9
				2	4.76 ± 0.51	46.1 ± 5.8
				3	2.48 ± 0.10	40.2 ± 2.6
			2018	1	4.47 ± 0.31	70.7 ± 23.6
				2	0.91 ± 0.10	24.2 ± 3.1
				3	1.66 ± 0.05	45.4 ± 1.7
		300	2017	1	5.82 ± 0.20	110.4 ± 10.6
				2	6.50 ± 0.52	97.0 ± 8.6
				3	5.82 ± 0.63	137.2 ± 17.0
			2018	1	4.64 ± 0.96	96.9 ± 39.1
				2	1.97 ± 0.24	48.8 ± 5.0
				3	1.95 ± 0.15	63.3 ± 4.9
	450	2017	1	6.31 ± 0.49	152.5 ± 17.0	
			2	6.64 ± 0.63	131.2 ± 13.2	
			3	5.19 ± 0.31	131.3 ± 12.1	
		2018	1	5.75 ± 0.28	141.3 ± 13.3	
			2	1.58 ± 0.22	40.9 ± 5.6	
			3	2.13 ± 0.33	77.3 ± 14.6	
	600	2017	1	6.69 ± 0.23	160.0 ± 13.8	
			2	6.27 ± 0.44	143.0 ± 7.8	
			3	4.27 ± 0.46	125.4 ± 13.7	
		2018	1	6.17 ± 0.13	118.5 ± 13.9	
			2	1.45 ± 0.05	34.4 ± 1.8	
			3	1.96 ± 0.27	87.0 ± 8.9	
RC	0	2017	1	6.61 ± 0.30	120.0 ± 7.4	
			2	10.39 ± 0.27	147.9 ± 8.7	
			3	9.05 ± 1.38	135.3 ± 22.8	
		2018	1	10.78 ± 0.58	128.4 ± 11.8	
			2	6.14 ± 2.10	100.8 ± 40.0	
			3	4.37 ± 0.41	88.4 ± 11.7	
	50	2017	1	9.16 ± 0.43	179.7 ± 5.8	
			2	10.02 ± 0.20	153.2 ± 8.0	
			3	9.87 ± 1.39	126.1 ± 18.1	
		2018	1	9.85 ± 0.84	112.6 ± 21.0	

				2	5.38 ± 1.87	75.4 ± 25.6
				3	4.40 ± 0.41	85.3 ± 14.2
NW	F	0	2017	1	6.58 ± 0.49	108.1 ± 11.5
				2	3.15 ± 0.18	41.4 ± 2.6
				3	4.84 ± 0.16	78.5 ± 3.1
				4	0.78 ± 0.10	16.4 ± 1.9
			2018	1	1.58 ± 0.14	17.4 ± 1.1
				2	0.85 ± 0.14	11.0 ± 1.5
				3	1.05 ± 0.44	21.7 ± 8.0
			75	2017	1	6.87 ± 0.28
		2			4.09 ± 0.47	53.9 ± 5.8
		3			4.82 ± 0.21	80.6 ± 4.1
		4			0.92 ± 0.31	21.5 ± 7.4
		2018		1	2.56 ± 0.21	31.8 ± 3.2
				2	1.82 ± 0.22	23.1 ± 2.1
				3	1.27 ± 0.16	26.1 ± 2.3
				4	1.09 ± 0.23	23.3 ± 5.0
		150	2017	1	7.09 ± 0.37	126.4 ± 4.7
				2	4.74 ± 0.44	75.2 ± 7.6
				3	5.10 ± 0.11	83.4 ± 6.0
				4	1.09 ± 0.23	23.3 ± 5.0
			2018	1	4.39 ± 0.15	60.4 ± 1.4
				2	2.61 ± 0.31	39.0 ± 3.5
				3	1.95 ± 0.38	47.8 ± 7.7
				4	1.50 ± 0.27	32.3 ± 5.9
		300	2017	1	7.04 ± 0.28	152.9 ± 5.8
				2	4.96 ± 0.59	97.8 ± 10.4
				3	4.84 ± 0.24	100.5 ± 3.4
				4	1.50 ± 0.27	32.3 ± 5.9
			2018	1	4.67 ± 0.27	86.8 ± 6.8
				2	2.98 ± 0.31	61.0 ± 6.4
				3	1.82 ± 0.40	59.0 ± 12.6
				4	2.22 ± 0.43	44.6 ± 8.5
		450	2017	1	8.27 ± 0.27	194.9 ± 14.1
				2	4.26 ± 0.33	108.8 ± 9.1
				3	4.21 ± 0.08	103.3 ± 4.4
				4	2.22 ± 0.43	44.6 ± 8.5
			2018	1	5.07 ± 0.42	115.1 ± 5.1
				2	3.16 ± 0.45	66.6 ± 10.4
				3	1.77 ± 0.41	58.3 ± 12.9
				4	1.91 ± 0.46	53.2 ± 16.2
		FC	0	2017	1	6.36 ± 0.21
2	2.46 ± 0.32				29.4 ± 3.0	
3	4.64 ± 0.20				103.3 ± 10.9	
4	1.91 ± 0.46				53.2 ± 16.2	
2018	1			2.31 ± 0.24	52.0 ± 8.7	
	2			1.28 ± 0.21	26.8 ± 3.8	
	3			1.31 ± 0.17	40.1 ± 5.2	
	4			1.91 ± 0.46	53.2 ± 16.2	
50	2017		1	7.51 ± 0.20	132.0 ± 9.2	
			2	3.11 ± 0.44	36.8 ± 5.8	

				3	5.13 ± 0.21	99.7 ± 3.2
				4	1.54 ± 0.36	38.7 ± 10.8
			2018	1	3.39 ± 0.26	61.8 ± 7.3
				2	1.26 ± 0.08	21.7 ± 2.2
				3	0.92 ± 0.08	24.4 ± 1.8
	R	0	2017	1	7.25 ± 0.13	103.7 ± 10.3
				2	3.03 ± 0.51	36.8 ± 7.2
				3	4.99 ± 0.44	82.5 ± 1.0
				4	0.91 ± 0.27	18.7 ± 5.9
			2018	1	1.57 ± 0.18	17.7 ± 2.4
				2	0.59 ± 0.06	8.7 ± 0.9
				3	0.75 ± 0.16	16.8 ± 3.9
		75	2017	1	8.18 ± 0.93	111.6 ± 10.4
				2	3.68 ± 0.33	54.1 ± 5.7
				3	4.59 ± 0.25	75.3 ± 2.7
			2018	4	0.86 ± 0.21	18.5 ± 4.9
	1			3.29 ± 0.17	36.9 ± 2.4	
	2			1.10 ± 0.25	17.3 ± 3.6	
	150	2017	3	1.42 ± 0.17	33.9 ± 3.5	
			1	7.98 ± 0.69	133.0 ± 6.3	
			2	4.74 ± 0.50	61.0 ± 3.3	
		2018	3	4.68 ± 0.32	81.6 ± 5.5	
			4	0.93 ± 0.17	17.9 ± 3.4	
			1	3.89 ± 0.15	51.0 ± 4.5	
	300	2017	2	1.92 ± 0.40	29.6 ± 4.9	
			3	1.76 ± 0.15	44.9 ± 2.7	
		2018	1	7.94 ± 0.13	141.7 ± 12.8	
			2	3.93 ± 0.33	92.4 ± 13.4	
			3	4.14 ± 0.26	93.6 ± 9.4	
	450	2017	4	1.33 ± 0.34	27.9 ± 8.8	
			1	5.11 ± 0.19	94.4 ± 5.3	
			2	2.62 ± 0.46	49.6 ± 7.0	
		2018	3	2.13 ± 0.36	60.1 ± 8.1	
			1	8.42 ± 0.31	186.3 ± 9.8	
2			3.54 ± 0.48	90.7 ± 14.5		
RC	0	2017	3	4.07 ± 0.22	107.3 ± 11.5	
			4	1.85 ± 0.39	40.3 ± 10.9	
		2018	1	5.43 ± 0.25	90.8 ± 7.0	
			2	2.40 ± 0.66	51.6 ± 12.5	
			3	1.66 ± 0.36	56.7 ± 10.4	
			2017	1	7.08 ± 0.36	107.1 ± 6.6
				2	2.58 ± 0.30	37.4 ± 5.6
			2018	3	3.85 ± 0.23	118.0 ± 8.9
				4	2.42 ± 0.37	65.6 ± 12.6
				1	2.73 ± 0.38	62.4 ± 9.2
			2	1.54 ± 0.30	41.3 ± 8.4	

				3	1.76 ± 0.18	53.4 ± 5.6
		50	2017	1	7.58 ± 0.42	132.3 ± 10.9
				2	2.88 ± 0.16	35.7 ± 2.9
				3	4.57 ± 0.25	120.6 ± 10.7
				4	2.26 ± 0.46	63.2 ± 16.3
			2018	1	3.96 ± 0.18	76.9 ± 11.1
				2	1.05 ± 0.18	21.6 ± 3.5
				3	1.17 ± 0.08	34.1 ± 3.1

13 **Table S3.** Herbage quality for individual herbage cuts for each sward treatment, at each site
14 and nitrogen application rate. HF = Henfaes experimental site, NW = North Wyke
15 experimental site. F = *festulolium*, R = ryegrass hybrid, FC = F with red clover, RC = R with red
16 clover. Values represent means \pm standard error ($n = 4$ at HF and 5 at NW).

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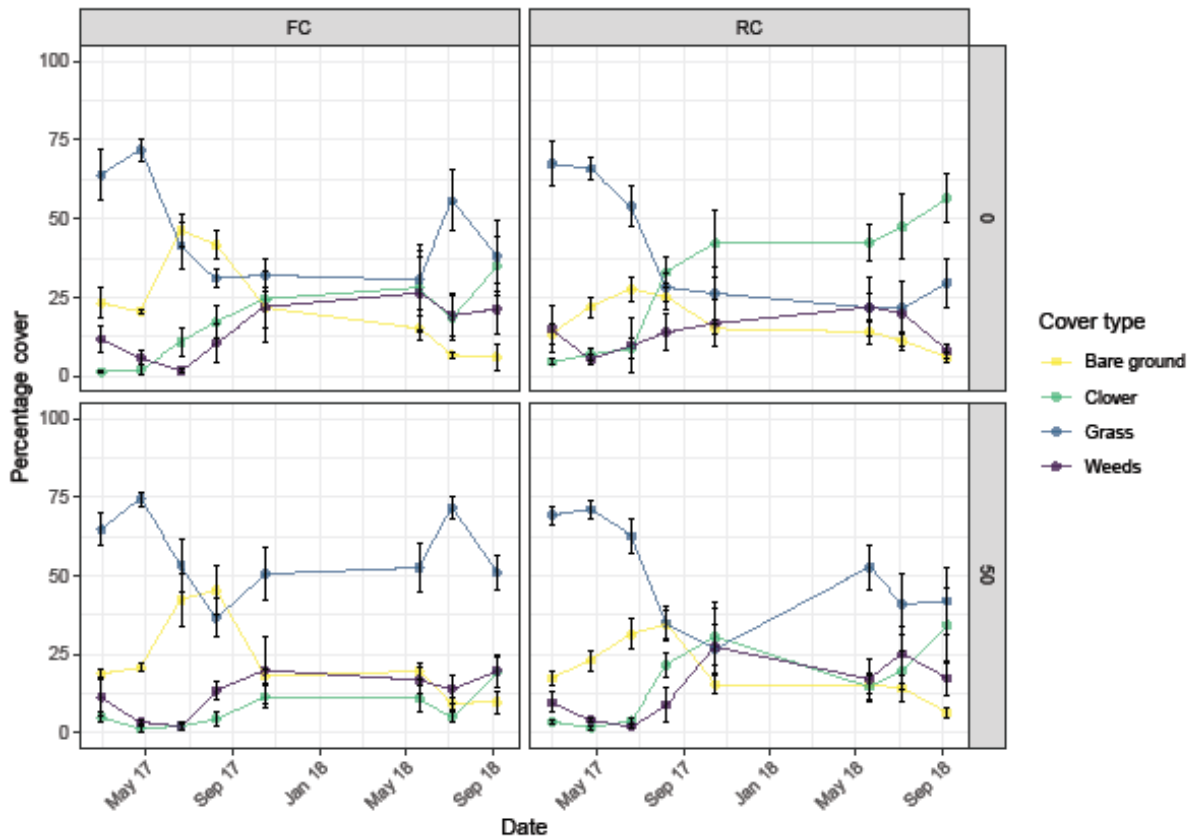
Site	Quality parameter	Sward treatment	N rate (kg N ha ⁻¹)	2017 Cut 1	2017 Cut 2	2017 Cut 3	2018 Cut 1	2018 Cut 2	2018 Cut 3		
HF	Crude protein (g kg ⁻¹ DM)	F	0	106 ± 4.1	104 ± 3.9	105 ± 2.6	140 ± 16.4	162 ± 21.7	163 ± 25.7		
			75	115 ± 13.0	101 ± 4.9	92 ± 4.7	111 ± 2.9	110 ± 13.8	114 ± 7.7		
			150	104 ± 3.7	107 ± 7.0	101 ± 3.4	116 ± 2.6	130 ± 11.4	139 ± 7.2		
			300	152 ± 25.2	98 ± 5.6	105 ± 5.0	131 ± 3.1	166 ± 12.4	179 ± 21.2		
			450	153 ± 26.7	118 ± 9.5	107 ± 11.5	131 ± 9.7	171 ± 18.2	160 ± 15.9		
			600	179 ± 18.0	142 ± 8.8	140 ± 5.1	116 ± 5.6	148 ± 23.9	176 ± 22.9		
		FC	0	119 ± 9.3	176 ± 42.6	185 ± 32.8	163 ± 3.1	172 ± 10.9	225 ± 19.4		
			50	111 ± 13.6	175 ± 26.2	181 ± 14.8	123 ± 9.7	179 ± 10.1	240 ± 25.1		
		R	0	107 ± 5.1	92 ± 1.2	95 ± 7.1	119 ± 6.5	134 ± 10.9	118 ± 17.9		
			75	102 ± 3.9	98 ± 5.6	95 ± 1.9	124 ± 6.5	154 ± 8.5	138 ± 18.6		
			150	114 ± 4.1	101 ± 7.3	90 ± 3.6	113 ± 6.0	208 ± 17.5	161 ± 12.2		
			300	166 ± 19.5	111 ± 7.4	102 ± 5.5	118 ± 8.3	172 ± 12.0	196 ± 14.9		
			450	142 ± 18.9	132 ± 14.0	119 ± 10.0	122 ± 0.8	199 ± 15.8	196 ± 30.4		
			600	133 ± 15.9	145 ± 17.7	121 ± 7.1	119 ± 7.7	187 ± 6.9	220 ± 32.8		
		RC	0	142 ± 22.6	112 ± 7.2	146 ± 28.1	160 ± 14.8	180 ± 12.0	280 ± 8.8		
			50	110 ± 13.3	153 ± 21.4	175 ± 16.6	121 ± 5.8	194 ± 11.1	203 ± 31.7		
			Metabolisable energy (MJ kg ⁻¹ DM)	F	0	11.7 ± 0.1	10.9 ± 0.2	11.0 ± 0.0	11.0 ± 0.1	10.1 ± 0.1	10.7 ± 0.1
					75	11.6 ± 0.1	10.8 ± 0.1	10.6 ± 0.1	11.3 ± 0.1	9.7 ± 0.2	10.7 ± 0.1
					150	11.7 ± 0.1	10.8 ± 0.1	10.4 ± 0.1	11.4 ± 0.1	9.6 ± 0.1	10.8 ± 0.1
					300	11.1 ± 0.2	10.4 ± 0.1	10.4 ± 0.1	10.9 ± 0.1	9.8 ± 0.0	10.9 ± 0.1
					450	11.1 ± 0.1	10.5 ± 0.1	10.3 ± 0.1	11.0 ± 0.1	9.7 ± 0.1	10.9 ± 0.1
					600	11.0 ± 0.2	10.6 ± 0.0	10.5 ± 0.1	11.0 ± 0.1	9.4 ± 0.2	11.0 ± 0.2
				FC	0	11.2 ± 0.2	10.9 ± 0.2	10.8 ± 0.1	10.9 ± 0.1	9.7 ± 0.1	10.8 ± 0.2
					50	11.3 ± 0.0	11.0 ± 0.2	10.9 ± 0.1	11.2 ± 0.1	9.8 ± 0.1	10.8 ± 0.0
R	0			11.5 ± 0.1	11.3 ± 0.1	11.1 ± 0.1	10.9 ± 0.1	10.2 ± 0.2	10.7 ± 0.1		
	75			11.3 ± 0.2	11.2 ± 0.2	11.1 ± 0.2	10.9 ± 0.1	10.1 ± 0.1	10.9 ± 0.1		
	150			11.2 ± 0.1	11.1 ± 0.1	10.9 ± 0.3	10.9 ± 0.2	10.1 ± 0.3	10.7 ± 0.1		
	300			10.8 ± 0.1	10.7 ± 0.1	10.8 ± 0.2	10.8 ± 0.1	10.1 ± 0.1	10.9 ± 0.2		
	450			11.3 ± 0.2	10.9 ± 0.0	10.9 ± 0.1	11.0 ± 0.0	10.1 ± 0.1	11.0 ± 0.1		
	600			11.1 ± 0.1	10.9 ± 0.1	10.5 ± 0.1	11.0 ± 0.1	9.9 ± 0.1	11.0 ± 0.1		
RC	0			11.1 ± 0.1	10.7 ± 0.1	10.7 ± 0.2	10.8 ± 0.1	9.8 ± 0.1	11.0 ± 0.1		
	50			11.4 ± 0.2	10.8 ± 0.1	11.0 ± 0.0	10.8 ± 0.1	9.9 ± 0.1	10.7 ± 0.1		
	Neutral detergent fibre (g kg ⁻¹ DM)			F	0	436 ± 21.4	492 ± 27.1	433 ± 9.6	389 ± 12.1	566 ± 14.4	402 ± 13.9
					75	413 ± 14.7	524 ± 20.3	486 ± 8.5	405 ± 12.9	603 ± 31.4	420 ± 17.2
					150	398 ± 13.4	492 ± 24.9	534 ± 19.6	393 ± 14.9	641 ± 16.2	428 ± 16.6

			300	457 ± 13.9	558 ± 5.8	577 ± 17.1	490 ± 16.7	621 ± 13.5	442 ± 16.4	
			450	469 ± 11.6	554 ± 20.8	601 ± 24.9	450 ± 21.7	639 ± 26.0	385 ± 19.1	
			600	457 ± 37.6	519 ± 7.0	532 ± 16.4	488 ± 24.9	642 ± 27.3	394 ± 38.2	
		FC	0	440 ± 20.8	474 ± 38.5	481 ± 9.7	420 ± 20.3	632 ± 20.7	435 ± 27.5	
			50	426 ± 18.0	447 ± 19.7	425 ± 22.2	431 ± 21.1	603 ± 10.0	402 ± 23.3	
		R	0	443 ± 13.4	406 ± 14.0	371 ± 11.5	468 ± 9.6	584 ± 28.4	395 ± 15.6	
			75	473 ± 11.6	445 ± 24.9	429 ± 19.2	474 ± 22.2	572 ± 10.0	413 ± 14.2	
			150	460 ± 36.6	462 ± 26.2	443 ± 24.6	439 ± 28.0	570 ± 44.9	455 ± 27.3	
			300	528 ± 43.2	551 ± 9.7	467 ± 23.7	456 ± 22.1	583 ± 19.6	453 ± 21.8	
			450	447 ± 12.7	488 ± 21.8	518 ± 24.5	441 ± 17.0	618 ± 38.1	390 ± 29.7	
		RC	600	467 ± 21.4	510 ± 10.3	566 ± 27.6	422 ± 14.1	609 ± 16.3	394 ± 28.6	
			0	459 ± 6.9	462 ± 40.4	492 ± 32.5	455 ± 11.5	599 ± 12.6	464 ± 26.5	
			50	467 ± 36.8	502 ± 40.1	482 ± 16.7	485 ± 6.0	595 ± 23.0	411 ± 12.4	
		Sugars (g kg ⁻¹ DM)	F	0	266 ± 14.5	233 ± 16.7	230 ± 4.9	201 ± 19.0	98 ± 9.5	179 ± 19.5
				75	238 ± 21.0	236 ± 14.2	237 ± 3.8	249 ± 13.5	116 ± 12.0	222 ± 19.2
	150			254 ± 13.3	231 ± 21.1	211 ± 26.9	262 ± 11.9	82 ± 7.2	189 ± 8.0	
	300			169 ± 18.2	157 ± 5.1	169 ± 9.8	200 ± 22.0	82 ± 10.6	148 ± 26.3	
	450			150 ± 14.4	148 ± 7.4	144 ± 9.7	225 ± 15.4	79 ± 6.5	192 ± 22.3	
	600			129 ± 4.0	137 ± 6.4	133 ± 9.7	178 ± 14.3	66 ± 4.7	186 ± 15.7	
	FC		0	188 ± 18.0	130 ± 25.0	120 ± 27.9	147 ± 11.2	52 ± 6.7	106 ± 18.4	
			50	210 ± 13.6	140 ± 22.1	147 ± 6.5	203 ± 15.2	59 ± 10.9	108 ± 27.7	
	R		0	249 ± 15.9	302 ± 11.6	279 ± 15.2	234 ± 12.7	119 ± 11.4	222 ± 19.7	
			75	211 ± 14.7	283 ± 11.6	254 ± 13.7	206 ± 15.0	95 ± 5.9	200 ± 23.7	
			150	216 ± 13.0	258 ± 9.4	251 ± 21.8	209 ± 19.9	73 ± 7.3	163 ± 13.6	
			300	125 ± 25.8	168 ± 9.4	223 ± 14.2	221 ± 16.4	92 ± 3.6	125 ± 20.1	
			450	168 ± 9.8	169 ± 10.6	180 ± 27.1	209 ± 15.6	78 ± 13.8	166 ± 37.8	
	RC		600	157 ± 12.9	162 ± 16.7	142 ± 8.2	216 ± 12.2	64 ± 5.6	145 ± 34.3	
0			168 ± 22.9	180 ± 19.3	151 ± 20.0	130 ± 14.7	49 ± 12.4	60 ± 19.6		
50			219 ± 20.0	155 ± 17.7	136 ± 13.8	174 ± 19.3	54 ± 7.2	130 ± 28.2		
NW	Crude protein (g kg ⁻¹ DM)		F	0	91 ± 5.8	62 ± 11.7	122 ± 4.5	70 ± 1.7	120 ± 2.8	191 ± 15.2
				75	102 ± 12.7	65 ± 2.7	111 ± 7.1	99 ± 5.1	139 ± 6.9	176 ± 16.6
		150		102 ± 6.3	88 ± 11.9	112 ± 5.7	111 ± 6.8	157 ± 5.8	201 ± 14.9	
		300		140 ± 10.0	128 ± 9.1	142 ± 8.2	139 ± 8.5	167 ± 10.9	245 ± 7.9	
		450		164 ± 15.2	151 ± 7.6	182 ± 9.5	150 ± 11.0	171 ± 8.6	252 ± 6.1	
	FC	0	86 ± 9.6	63 ± 1.8	152 ± 10.4	119 ± 21.4	149 ± 11.7	209 ± 5.4		
		50	103 ± 6.2	71 ± 7.4	128 ± 7.8	101 ± 4.4	121 ± 6.0	188 ± 12.1		
	R	0	74 ± 4.1	63 ± 1.6	124 ± 12.4	76 ± 0.6	121 ± 6.8	158 ± 7.5		

			75	87 ± 8.7	83 ± 6.1	125 ± 9.9	94 ± 4.8	140 ± 5.0	183 ± 11.8	
			150	115 ± 14.2	80 ± 6.3	119 ± 2.5	109 ± 5.9	144 ± 2.7	168 ± 10.6	
			300	125 ± 5.2	134 ± 6.9	186 ± 11.3	139 ± 9.2	190 ± 6.2	234 ± 6.3	
			450	140 ± 7.8	129 ± 11.8	195 ± 12.1	142 ± 11.9	197 ± 8.4	249 ± 10.1	
		RC	0	71 ± 4.7	72 ± 4.4	174 ± 20.1	146 ± 16.4	177 ± 5.6	214 ± 10.6	
			50	102 ± 5.3	65 ± 0.9	175 ± 24.1	121 ± 12.8	144 ± 9.9	196 ± 4.8	
Metabolisable energy (MJ kg ⁻¹ DM)	F		0	12.2 ± 0.1	10.5 ± 0.2	9.8 ± 0.1	11.6 ± 0.2	10.6 ± 0.1	11.6 ± 0.2	
			75	12.3 ± 0.1	10.4 ± 0.4	9.9 ± 0.2	11.8 ± 0.2	10.8 ± 0.1	11.3 ± 0.2	
			150	11.9 ± 0.1	10.0 ± 0.2	9.2 ± 0.2	11.5 ± 0.1	10.5 ± 0.1	11.2 ± 0.2	
			300	12.1 ± 0.1	9.7 ± 0.3	9.1 ± 0.2	11.3 ± 0.1	10.4 ± 0.2	11.3 ± 0.3	
			450	11.9 ± 0.2	9.9 ± 0.2	9.7 ± 0.1	11.1 ± 0.1	10.4 ± 0.1	11.5 ± 0.3	
	FC		0	12.1 ± 0.1	10.6 ± 0.2	10.2 ± 0.1	11.8 ± 0.2	10.9 ± 0.2	11.7 ± 0.2	
			50	12.1 ± 0.1	10.3 ± 0.3	10.1 ± 0.2	11.6 ± 0.1	10.8 ± 0.1	11.5 ± 0.2	
	R		0	12.1 ± 0.1	10.8 ± 0.4	10.9 ± 0.2	11.5 ± 0.1	10.9 ± 0.1	11.7 ± 0.1	
			75	12.4 ± 0.2	10.7 ± 0.1	10.7 ± 0.3	11.3 ± 0.2	11.0 ± 0.1	11.6 ± 0.2	
			150	12.4 ± 0.2	10.6 ± 0.3	10.7 ± 0.3	11.4 ± 0.1	11.1 ± 0.1	11.6 ± 0.1	
			300	12.2 ± 0.1	10.5 ± 0.2	10.2 ± 0.1	10.9 ± 0.1	11.1 ± 0.1	11.7 ± 0.1	
			450	12.3 ± 0.1	10.1 ± 0.1	10.3 ± 0.1	11.1 ± 0.1	11.2 ± 0.1	11.8 ± 0.3	
	RC		0	12.4 ± 0.1	11.2 ± 0.1	11.1 ± 0.1	11.7 ± 0.1	11.4 ± 0.1	11.8 ± 0.2	
			50	12.1 ± 0.1	10.5 ± 0.1	10.9 ± 0.1	11.2 ± 0.1	11.0 ± 0.1	11.7 ± 0.2	
	Neutral detergent fibre (g kg ⁻¹ DM)	F		0	329 ± 7.2	459 ± 13.6	551 ± 7.4	377 ± 14.6	541 ± 22.0	450 ± 6.2
				75	325 ± 11.0	467 ± 28.2	555 ± 14.6	348 ± 10.5	535 ± 27.6	476 ± 16.9
				150	352 ± 10.7	502 ± 15.0	649 ± 45.2	396 ± 16.9	555 ± 11.0	487 ± 13.2
				300	336 ± 12.7	539 ± 15.3	598 ± 10.6	405 ± 9.0	550 ± 12.5	488 ± 32.3
			450	362 ± 24.6	522 ± 15.1	572 ± 8.7	414 ± 6.3	537 ± 12.8	473 ± 25.3	
FC			0	365 ± 17.9	457 ± 10.4	520 ± 9.2	371 ± 9.6	496 ± 20.3	436 ± 19.8	
			50	347 ± 7.7	476 ± 21.2	557 ± 19.6	372 ± 16.5	521 ± 15.3	455 ± 23.7	
R			0	349 ± 13.9	431 ± 16.0	477 ± 30.0	376 ± 18.9	506 ± 10.8	429 ± 17.0	
			75	329 ± 20.0	447 ± 13.8	499 ± 27.4	396 ± 14.3	510 ± 7.0	464 ± 19.6	
			150	326 ± 16.7	445 ± 7.8	482 ± 17.0	391 ± 9.5	501 ± 10.2	425 ± 23.5	
			300	329 ± 13.7	473 ± 4.8	579 ± 21.8	432 ± 10.8	503 ± 6.6	460 ± 8.8	
			450	334 ± 14.2	489 ± 8.2	588 ± 47.0	413 ± 12.7	493 ± 11.3	442 ± 31.3	
RC			0	321 ± 7.2	394 ± 11.9	468 ± 7.9	359 ± 10.7	439 ± 10.0	419 ± 13.5	
			50	346 ± 9.5	448 ± 9.9	492 ± 7.7	405 ± 12.4	478 ± 19.7	430 ± 17.7	
Sugars (g kg ⁻¹ DM)		F		0	145 ± 5.54	111 ± 6.88	52.6 ± 4.48	135 ± 4.80	66.4 ± 5.31	65.6 ± 6.71
				75	146 ± 6.33	108 ± 8.83	62.8 ± 10.1	136 ± 6.90	67.6 ± 10.1	66.0 ± 3.66
				150	135 ± 5.86	83 ± 9.16	36.0 ± 10.2	128 ± 6.61	56.6 ± 2.14	59.2 ± 3.31

			300	124 ± 2.63	50 ± 3.04	34.2 ± 3.57	115 ± 5.10	55.4 ± 3.37	49.8 ± 7.51
			450	114 ± 10.7	50 ± 6.10	31.6 ± 3.70	112 ± 4.97	57.6 ± 2.66	54.2 ± 5.17
		FC	0	137 ± 7.78	113 ± 2.35	42.3 ± 9.66	111 ± 13.4	53.8 ± 3.29	41.6 ± 4.43
			50	140 ± 2.60	100 ± 3.92	50.0 ± 4.63	126 ± 6.50	72.6 ± 2.42	55.8 ± 2.08
		R	0	150 ± 8.58	124 ± 9.92	87.8 ± 14.5	135 ± 6.57	77.4 ± 0.98	75.2 ± 7.29
			75	152 ± 5.40	105 ± 8.22	80.2 ± 9.21	132 ± 5.48	72.4 ± 4.50	75.4 ± 1.91
			150	144 ± 8.43	110 ± 6.30	86.2 ± 6.26	132 ± 4.38	74.4 ± 6.48	69.2 ± 10.8
			300	139 ± 6.64	79 ± 4.12	34.0 ± 7.06	106 ± 2.67	65.8 ± 1.32	63.0 ± 4.53
			450	134 ± 6.73	74 ± 8.01	37.9 ± 12.7	112 ± 6.45	73.4 ± 2.38	61.4 ± 5.56
		RC	0	159 ± 2.50	123 ± 1.66	40.3 ± 18.8	97 ± 8.55	52.0 ± 3.62	44.6 ± 5.83
50	136 ± 3.61		111 ± 2.63	56.3 ± 16.7	105 ± 6.68	54.0 ± 6.20	58.8 ± 4.71		

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20 **Figure S1.** Bare ground, clover, grass and weeds cover for the mixed swards at the North Wyke site.
 21 Where FC is *festulolium* with clover and RC is ryegrass with clover; values are mean ($n = 5$) ± standard
 22 error, the 0 and 50 row labels refer to the nitrogen application rate (as kg N ha⁻¹).