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Table 1 Treatment crops and test crops[a], 1973–1997, Block III[b], Woburn Ley–arable experiment.

	Continuous rotations				Alternating rotatic	
	Arable		Ley–arable		1st cycle	
Year	AB[c]	AF[d]	Ln3[e]	Lc3[f]	Ln8[i]	Lc8[j]
1973	P	P	Ln1	Lc1	Ln1	Lc1
1974	B	B	Ln2	Lc2	Ln2	Lc2
1975	H	B	Ln3	Lc3	Ln3	Lc3
1976	W	W	W	W	Ln4	Lc4
1977	B	B	B	B	Ln5	Lc5
1978	B	F	Ln1	Lc1	Ln6	Lc6
1979	B	F	Ln2	Lc2	Ln7	Lc7
1980	O	O	Ln3	Lc3	Ln8	Lc8
1981	W	W	W	W	W	W
1982	B	B	B	B	B	B
1983	B	F	Ln1	Lc1	Ln1	Lc1
1984	B	F	Ln2	Lc2	Ln2	Lc2
1985	BE	BE	Ln3	Lc3	Ln3	Lc3
1986	W	W	W	W	Ln4	Lc4
1987	B	B	B	B	Ln5	Lc5
1988	B	F	Ln1	Lc1	Ln6	Lc6
1989	B	F	Ln2	Lc2	Ln7	Lc7
1990	BE	BE	Ln3	Lc3	Ln8	Lc8
1991	W	W	W	W	W	W
1992	R	R	R	R	R	R
1993	B	F	Ln1	Lc1	Ln1	Lc1
1994	B	F	Ln2	Lc2	Ln2	Lc2
1995	BE	BE	Ln3	Lc3	Ln3	Lc3
1996	W	W	W	W	Ln4	Lc4
1997	R	R	R	R	Ln5	Lc5

P, potatoes: H, 1–yr hay: F, fallow: O, winter oats: BE, winter beans: W, winter wheat: B, spring barley: R, winte
Ln1–Ln8, first, second, third year *etc.* of a grass+N ley: Lc1–Lc8, first, second, third year *etc.* of a grass+clover l

Each of the eight rotations (AB, AF *etc.*) were grown on pairs of plots in each of five blocks. One plot in each pair received FYM; 38 t ha^{-1} applied every fifth year until the mid-1960s. The last applications of FYM were to Blocks IV, II, I, III and V in 1963, 1964, 1965, 1966 and 1967 respectively.

[a] Test crops are highlighted. Plots were divided to test four rates of N when test crops were grown. The rates of N rotated so that, over time, the C inputs on the four subplots were similar.

[b] Treatment cropping started in 1938 on Block III, and in 1939, 1940, 1941, 1942 on Blocks V, IV, II and I respectively.

[c] AB treatment crops: potatoes, cereal, 1–year hay from 1938–75; barley, barley, beans (or oats) from 1978–95.

[d] AF treatment crops: potatoes, cereal, root crop from 1938–75; fallow, fallow, beans from 1978–95.

[e] Ln3 treatment crop: 3–year grazed grass+clover leys with N from 1938–70; 3–year grass leys with N since 197

[f] Lc3 treatment crop: 3–year lucerne or sainfoin leys from 1938–70; 3–year grass+clover leys since 1973.

[g] On four pairs of plots treatment crops alternated between arable and ley rotations.

[h] The alternating rotations were replaced by 8–year grass leys with N or 8–year grass+clover leys. The 1st cycle of these longer leys started in 1973 on Block III and in 1974, 1975, 1976, 1977 on Blocks V, IV, II and I respectively. The 2nd cycle of 8-yr leys started in 1978 on Block III and in 1979, 1980, 1981, 1982 on Blocks V, IV, II and I respectively. The delay in starting the 2nd cycle of 8–year leys meant that the effects of all of the different treatment rotations on the yield of the following test crops could be measured every five years.

[i] Ln8 treatment crop: alternating treatment crops from 1938–70; 8–year grass leys with N since 1973 (1st cycle).

[j] Lc8 treatment crop: alternating treatment crops from 1938–70; 8–year grass+clover leys since 1973 (1st cycle).

[k] Ln8 treatment crop: alternating treatment crops from 1938–75; 8–year grass leys with N since 1978 (2nd cycle)

[l] Lc8 treatment crop: alternating treatment crops from 1938–75; 8–year grass+clover leys since 1978 (2nd cycle).

ons[g] then 8–year leys[h]		
	2nd cycle	
	Ln8[k]	Lc8[l]
	P	P
	B	B
	H	B
	W	W
	B	B
	Ln1	Lc1
	Ln2	Lc2
	Ln3	Lc3
	Ln4	Lc4
	Ln5	Lc5
	Ln6	Lc6
	Ln7	Lc7
	Ln8	Lc8
	W	W
	B	B
	Ln1	Lc1
	Ln2	Lc2
	Ln3	Lc3
	Ln4	Lc4
	Ln5	Lc5
	Ln6	Lc6
	Ln7	Lc7
	Ln8	Lc8
	W	W
	R	R

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Table 2 Effect of preceeding cropping on the grain yield, grain N content and % recovery of fertiliser N by the grain of tl 1st and 2nd test crops, Woburn Ley-arable experiment.

	Grain yield, t ha^{-1} at 85% dry matter				Grain N content, kg ha^{-1}			
	1st test crop, winter wheat, 20 yr average, 1981-2000							
	N applied[a], kg ha^{-1}							
Rotation[b]	0	70	140	210	0	70	140	210
AB	2.81	5.83	6.73	7.06	40	85	118	138
AF	2.60	6.20	7.45	7.89	38	89	125	150
Ln3	3.78	6.55	7.43	7.62	56	101	134	149
Ln8	4.24	6.81	7.54	7.39	61	106	136	144
Lc3	5.26	7.55	8.02	7.88	78	123	149	158
Lc8	5.18	7.47	7.77	7.76	78	125	145	155
Within Rotation	F-ratio$_{(5\ 95)}$ = 13.87, $p < 0.001$				F-ratio$_{(5\ 95)}$ = 24.79, $p < 0.001$			
SED	0.226				3.65			
Rotation * N	F-ratio$_{(15\ 684)}$ = 11.05, $p < 0.001$				F-ratio$_{(15\ 684)}$ = 4.95, $p < 0.001$			
SED	0.283				4.92			
	2nd test crop, spring barley, 9 yr average, 1982-1991[c]							
	N applied, kg ha^{-1}							
	0	60	120	180	0	60	120	180
AB	2.29	4.56	5.41	5.14	32	64	87	91
AF	1.87	4.61	5.51	5.56	28	64	85	97
Ln3	4.15	5.69	5.93	5.59	57	85	100	102
Ln8	4.45	5.70	5.82	5.43	62	87	98	101
Lc3	4.16	5.64	5.85	5.39	60	87	101	99
Lc8	4.61	5.98	5.92	5.69	65	93	102	105
Within Rotation	F-ratio$_{(5\ 40)}$ = 24.63 , $p < 0.001$				F-ratio$_{(5\ 40)}$ = 28.90, $p < 0.001$			
SED	0.149				2.73			
Rotation * N	F-ratio$_{(15\ 288)}$ = 12.22, $p < 0.001$				F-ratio$_{(15\ 288)}$ = 4.24, $p < 0.001$			
SED	0.232				4.45			
	2nd test crop, winter rye, 5 yr average, 1997-2001							
	N applied, kg ha^{-1}							
	0	40	80	120	0	40	80	120
AB	3.19	5.00	6.44	6.92	30	48	67	81
AF	2.48	4.44	5.55	6.32	23	40	54	72
Ln3	5.05	6.61	7.42	7.14	49	67	83	91
Ln8	5.35	6.91	7.56	7.64	55	70	87	96
Lc3	4.97	6.43	7.21	7.12	50	67	82	90
Lc8	4.98	6.77	7.16	7.12	51	72	85	93
Within Rotation	F-ratio$_{(5\ 20)}$ = 15.47, $p < 0.001$				F-ratio$_{(5\ 20)}$ = 22.24, $p <0.001$			
SED	0.302				3.60			
Rotation * N	F-ratio$_{(15\ 144)}$ = 1.94, $p < 0.05$				F-ratio$_{(15\ 144)}$ = 0.75, not significant			
SED	0.451				5.05			

[a] In 1981 wheat received 0, 63, 126, 189 kgN ha^{-1}

[b] For rotation cropping see text

[c] Excludes 1983 as extra N was applied to all except N0 plots

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Recovery of fertilizer N by grain, %		
70	140	210
65	56	47
73	62	54
65	56	45
65	54	40
65	51	38
67	48	37
60	120	180
53	46	33
60	48	38
47	36	25
42	30	22
45	34	22
47	31	22
40	80	120
45	46	43
43	39	41
45	43	35
38	40	34
43	40	33
53	43	35

Table 3 Estimated mean maximum yields, Ymax, and associated mean nitrogen application, Nmax , in the model for winter wheat, spring barley and winter rye, Woburn Ley-arable experiment.

	Winter wheat 1981-2000		Spring barley 1982-1991[a]		Winte 1997-
Rotation	Ymax, t ha^{-1}	Nmax, kg ha^{-1}	Ymax, t ha^{-1}	Nmax, kg ha^{-1}	Ymax, t ha^{-1}
AB mean	7.10 (0.427)	175 (5.9)	5.34 (0.606)	140 (7.6)	7.07 (0.741)
range	2.87-10.32	102-217	2.10-8.11	105-176	4.60-9.02
AF mean	7.91 (0.316)	192 (5.0)	5.76 (0.515)	150 (6.0)	6.25 (0.751)
range	4.89-10.94	154-224	3.68-8.13	125-183	5.07-8.28
Ln3 mean	7.67 (0.308)	170 (4.8)	5.99 (0.453)	113 (6.6)	7.49 (0.820)
range	5.10-10.21	125-205	3.96-7.96	72-136	5.14-9.82
Ln8 mean	7.63 (0.266)	160 (3.8)	5.85 (0.474)	102 (5.5)	7.88 (0.787)
range	5.56-9.97	122-185	3.62-7.83	72-133	5.33-9.73
Lc3 mean	8.20 (0.281)	147 (7.9)	5.84 (0.525)	107 (5.5)	7.49 (0.873)
range	6.29-10.62	38-189	3.42-8.12	84-128	5.14-9.82
Lc8 mean	8.03 (0.288)	145 (7.7)	6.10 (0.486)	104 (4.1)	7.41 (0.812)
range	6.27-10.27	55-193	3.79-8.24	86-114	5.05-10.18

[a] The 1983 data for spring barley was not used in the response curve fitting exercise as an extra 60 kgN ha^{-1} was applied to all, except the N0, treatments following prolonged heavy rain in April and May.

Figures in parentheses are standard errors for Ymax and Nmax derived from the estimated values for each year.

er rye
-2001
Nmax, kg ha^{-1}
125 (12.1)
50-128
125 (6.3)
107-146
96 (10.5)
61-136
99 (12.0)
50-128
97 (14.9)
41-125
95 (10.3)
62-131

Table 4 Vertical and horizontal shifts required to bring the fitted yield response curves for five rotations into coincidence with that for the AB rotation, Woburn Ley-arable experiment.

Rotation	Winter wheat 1981-2000		Spring barley 1982-1991[a]		Winter rye 1997-2001	
	Vertical shift[b]	Horizontal shift[c]	Vertical shift[b]	Horizontal shift[c]	Vertical shift[b]	Horizontal shift[c]
AF	0.81 (0.102)	-17 (3.0)	0.42 (0.098)	-10 (3.2)	-0.82 (0.23)	0 (5.9)
Ln3	0.57 (0.098)	5 (3.2)	0.62 (0.092)	27 (3.9)	0.42 (1.70)	29 (6.5)
Ln8	0.53 (0.097)	15 (3.4)	0.51 (0.090)	38 (4.3)	0.81 (1.59)	26 (6.4)
Lc3	1.10 (0.096)	28 (3.8)	0.50 (0.091)	33 (4.1)	0.44 (1.68)	28 (6.5)
Lc8	0.93 (0.096)	30 (3.8)	0.76 (0.091)	35 (4.2)	0.34 (1.79)	30 (6.6)

[a] The 1983 data for spring barley was not used in the response curve fitting exercise as an extra 60 kgN ha^{-1} was applied to all, except the N0, treatments following prolonged heavy rain in April and May.

[b] Vertical shift is the estimated shift in maximum yield, t ha^{-1}, compared to the yield in the AB rotation. A negative value indicates that the fitted yield was lower than that for the AB rotation.

[c] Horizontal shift is the estimated shift in effective spring applied N fertilizer, kg ha^{-1}, compared to the AB rotation. A negative value indicates that more N was required to achieve the same yield as that in the AB rotation.

Figures in parentheses are the standard errors of the estimated vertical and horizontal shifts.

Table 5 Regression coefficients for the yield of wheat[a] given no fertilizer N versus % N in soil[b], Woburn Ley-arable.

Source	Estimate	S.E.	t(154)	*P*
%N in soil	38.53	5.370	7.17	<0.001
Block I	-0.917	0.493	-1.86	0.065
Block II	-0.793	0.561	-1.41	0.159
Block III	0.345	0.572	0.60	0.547
Block IV	-0.669	0.632	-1.06	0.282
Block V	-0.063	0.586	-0.11	0.915
Source	Estimate	S.E.	t(152)	*P*
Rotation AB	-3.93	1.17	-3.35	0.001
Rotation AF	-1.03	1.10	-0.93	0.352
Rotation Ln3	0.64	1.59	0.40	0.686
Rotation Ln8	5.05	1.81	2.78	0.006
%N.Rotation AB	73.8	12.7	5.82	<0.001
%N.Rotation AF	46.7	14.0	3.34	0.001
%N.Rotation Ln3	27.7	13.9	1.99	0.048
%N.Rotation Ln8	-7.3	16.4	-0.45	0.655

[a] Yield of winter wheat grain, t/ha at 85% dry matter, 1981-2000. Grown on each of the five blocks in four of the 20 years.

[b] Soil sampled prior to ploughing and drilling winter wheat.

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