

APPENDIX B

Site reference: 01

Year: 1998

Topsoil texture:	Sandy clay loam	Previous crop:	Winter barley
Current crop:	Winter OSR	Expected mkt yield t/ha:	4.0
Maximum mkt yield t/ha:	3.4	Maximum total DW t/ha:	5.9

Summary of N recommendations (kgN/ha) and calculated yields (t/ha):

Method	Optimum*	RB209	Farm [§]	WELL_N:				SUNDIAL-FRS:			
				Predictive		Retrospective		Predictive		Retrospective	
				Default weather	Actual weather	Default weather	Actual weather	Default weather	+ spring SMN	Actual weather	+ spring SMN
Recommendation	See below	190	188	N/A	N/A	N/A	N/A	200	159	120	89
Calculated yield *	N/A	3.1	3.1					3.2	2.9	2.7	2.6
% difference from optimum yield											

* Calculated from linear plus exponential curve fitted to trial data.

§ Farm recommendation is actual rate used by the farmer in the rest of the field.

Comments: There was a linear response to applied N and no optimum could be fitted. Yield variability increased significantly above applications of 250 kgN/ha. The SUNDIAL-FRS predictive recommendation (default weather) was very close to the farm yield. Using actual weather and spring SMN reduced the recommendation. The SUNDIAL-FRS recommendation is probably too low for this expected yield at this site. The recommendation given by RB209 was also too low.

WELL_N is not parameterised for oil seed rape.

Crop N uptake and Soil Mineral N (SMN, nitrate plus ammonium) at harvest (kgN/ha)

N rate*	Crop N uptake	SMN 0-30cm	SMN 30-60cm	SMN 60-90cm	Crop N + SMN
Measured values					
0	76	67	23	18	184
300	130	184	33	16	363
188 (farm) [§]	N/A	75	32	12	N/A
WELL_N Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	N/A	N/A	N/A	N/A	
300	N/A	N/A	N/A	N/A	
SUNDIAL-FRS Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	62	13	13	12	100
300	199	15	130	34	378
188 (farm) [§]	164	15	81	22	282

* Zero and maximum rates used in trial, plus farm rate[§] where available.

Comments: SUNDIAL simulated crop N well at the zero N rate, but underestimated SMN. Where fertiliser N had been applied, SUNDIAL overestimated crop N, but simulated total SMN reasonably well, although the distribution of SMN in the profile was not correct.

APPENDIX B

Site reference: 01

Year: 1999

Topsoil texture:	Sandy clay loam	Previous crop:	Winter OSR
Current crop:	Winter wheat	Expected mkt yield t/ha:	10.5
Maximum mkt yield t/ha:	9.9	Maximum total DW t/ha:	16.1

Summary of N recommendations (kgN/ha) and calculated yields (t/ha):

Method	Optimum*	RB209	Farm [§]	WELL_N:				SUNDIAL-FRS:			
				Predictive		Retrospective		Predictive		Retrospective	
				Default weather	Actual weather	Default weather	Actual weather	Default weather	+ spring SMN	Actual weather	+ spring SMN
Recommendation	See below	200	136	175	150	175	150	240	160	280	200
Calculated yield *	N/A	8.8	8.0	8.5	8.2	8.5	8.2	9.2	8.3	9.7	8.8
% difference from optimum yield											

* Calculated from linear plus exponential curve fitted to trial data.

§ Farm recommendation is actual rate used by the farmer in the rest of the field.

Comments: There was a linear response to applied N and no optimum could be fitted. The expected yield was not achieved on the trial, yet the farm rate of 136 kgN/ha used in the remainder of the field gave a measured yield of 11.8 t/ha. The farm N was applied 2 weeks later than the trial N (20/4/99 compared to 5/4/99) and appears to have been used much more efficiently. This illustrates the importance of timing, and indicates that there was considerable yield variability across the field.

The SUNDIAL-FRS retrospective recommendation (without spring SMN) was the greatest for this site. The use of the spring SMN measurements reduced the recommendation, and would have resulted in reduced yields. WELL_N gave recommendations close to RB209 and farm practice and were reduced by 25 kgN/ha by actual weather.

Crop N uptake and Soil Mineral N (SMN, nitrate plus ammonium) at harvest (kgN/ha)

N rate*	Crop N uptake	SMN 0-30cm	SMN 30-60cm	SMN 60-90cm	Crop N + SMN
Measured values					
0	69	52	25	14	160
250	244	60	25	12	341
136 (farm) [§]	217	36	14	12	279
WELL_N Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	109	18	7	6	140
250	260	18	7	6	291
SUNDIAL-FRS Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	94	34	46	12	186
250	240	39	77	12	368
136 (farm) [§]	215	32	20	12	279

* Zero and maximum rates used in trial, plus farm rate[§] where available.

Comments: SUNDIAL simulated crop N and SMN well for all the N rates. WELL_N simulated crop + soil N well at both zero and maximum rates, but underestimated SMN, particularly in the 0-30cm layer.

APPENDIX B

Site reference: **02**

Year: **1998**

Topsoil texture:	Sandy clay loam	Previous crop:	Winter wheat
Current crop:	Winter barley	Expected mkt yield t/ha:	7.5
Maximum mkt yield t/ha:	6.6	Maximum total DW t/ha:	12.1

Summary of N recommendations (kgN/ha) and calculated yields (t/ha):

Method	Optimum*	RB209	Farm [§]	WELL_N:				SUNDIAL-FRS:			
				Predictive		Retrospective		Predictive		Retrospective	
				Default weather	Actual weather	Default weather	Actual weather	Default weather	+ spring SMN	Actual weather	+ spring SMN
Recommendation	0	160	202	125	150	125	150	40	0	60	0
Calculated yield *	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8
% difference from optimum yield											

* Calculated as mean trial yield, as there was no significant response to N within the range of the trial.

§ Farm recommendation is actual rate used by the farmer in the rest of the field.

Comments: There was no significant response to applied N, with very variable results in the field trial caused by lodging. SUNDIAL correctly recommended that no fertiliser N should be applied, when spring SMN measurements were included. All other recommendations were too high. The interactive effects of increased N applications, increased grain fill and lodging make it difficult to draw any conclusions from this data set.

Crop N uptake and Soil Mineral N (SMN, nitrate plus ammonium) at harvest (kgN/ha)

N rate*	Crop N uptake	SMN 0-30cm	SMN 30-60cm	SMN 60-90cm	Crop N + SMN
Measured values					
0	82	54	31	21	188
160	208	116	33	27	384
202 (farm) [§]	N/A	96	38	19	
WELL_N Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	90	7	6	5	108
160	190	7	6	5	208
SUNDIAL-FRS Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	81	19	37	19	157
160	128	23	92	32	275
202 (farm) [§]	135	23	71	58	287

* Zero and maximum rates used in trial, plus farm rate[§] where available.

Comments: SUNDIAL-FRS simulated crop N and SMN well in the zero N treatment, but underestimated crop N at the maximum N rate. Total SMN at the maximum N rate was reasonably well simulated, but the distribution within the profile was again wrong (as in Site 1/98). Total crop N uptake at the maximum N rate was high, suggesting that SUNDIAL-FRS was unable to simulate luxury N uptake. A variable nitrogen uptake module for SUNDIAL has been developed in earlier work and could be implemented in this version of the model if the results suggest that this is necessary. WELL_N simulated crop N uptake very well, but considerably underestimated SMN.

APPENDIX B

Site reference: 02

Year: 1999

Topsoil texture:	Sandy clay loam	Previous crop:	Winter barley
Current crop:	Winter OSR	Expected mkt yield t/ha:	4.5
Maximum mkt yield t/ha:	4.5	Maximum total DW t/ha:	11.0

Summary of N recommendations (kgN/ha) and calculated yields (t/ha):

Method	Optimum*	RB209	Farm [§]	WELL_N:				SUNDIAL-FRS:			
				Predictive		Retrospective		Predictive		Retrospective	
				Default weather	Actual weather	Default weather	Actual weather	Default weather	+ spring SMN	Actual weather	+ spring SMN
Recommendation	0 (see below)	190	225	N/A	N/A	N/A	N/A	160	141	180	140
Calculated yield *	3.9	3.9	3.9					3.9	3.9	3.9	3.9
% difference from optimum yield											

* Calculated as mean trial yield, as there was no significant response to N within the range of the trial.

§ Farm recommendation is actual rate used by the farmer in the rest of the field.

Comments: A basal application of 45 kgN/ha was applied to all plots and the farm area in September 1998. There was no significant response to additional N at this site, and very high variability between the field replicates. The farm rate of 225 kgN/ha used in the remainder of the field produced a higher yield (4.8 t/ha) than the trial area, and left very little SMN at harvest. This implies that the timing of the N applications was very important. The farm N was applied 2 weeks earlier than the trial N. The SUNDIAL-FRS and RB209 recommendations were all too high, although the SUNDIAL recommendation was reduced when spring SMN measurements were used. The difficulty in determining an optimum N rate may be due to spatial variability in the field. High spatial variability will also make accurate fertiliser recommendation difficult. Where spatial variability is high, the variation should be accounted for in the recommendations.

WELL_N is not parameterised for oil seed rape.

Crop N uptake and Soil Mineral N (SMN, nitrate plus ammonium) at harvest (kgN/ha)

N rate*	Crop N uptake	SMN 0-30cm	SMN 30-60cm	SMN 60-90cm	Crop N + SMN
Measured values					
0	124	66	15	15	220
300	212	147	51	37	447
225 (farm) [§]	270	6	12	13	301
WELL_N Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	N/A	N/A	N/A	N/A	
300	N/A	N/A	N/A	N/A	
SUNDIAL-FRS Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	163	12	12	12	199
300	205	17	144	24	390
225 (farm) [§]	267	15	14	12	308

* Zero and maximum rates used in trial, plus farm rate[§] where available.

Comments:

SUNDIAL-FRS simulated crop N uptake and SMN very well under the farm conditions, and reasonably well in the trial.

APPENDIX B

Site reference: 03a

Year: 1998

Topsoil texture:	Silt loam	Previous crop:	Winter OSR
Current crop:	Winter wheat	Expected mkt yield t/ha:	11.0
Maximum mkt yield t/ha:	11.5	Maximum total DW t/ha:	16.3

Summary of N recommendations (kgN/ha) and calculated yields (t/ha):

Method	Optimum*	RB209	Farm [§]	WELL_N:				SUNDIAL-FRS:			
				Predictive		Retrospective		Predictive		Retrospective	
				Default weather	Actual weather	Default weather	Actual weather	Default weather	+ spring SMN	Actual weather	+ spring SMN
Recommendation	136 (±7.6)	90	175	150	125	125	125	280	260	280	260
Calculated yield *	11.4	10.3	10.9	11.5	11.3	11.3	11.3	N/A	N/A	N/A	N/A
% difference from optimum yield		-10	-5	0	-1	-1	-1				

* Calculated from linear plus exponential curve fitted to trial data. Estimated standard error given in brackets.

§ Farm recommendation is actual rate used by the farmer in the rest of the field.

Comments: The SUNDIAL-FRS recommendations were outside the range of N rates applied in the trial, thus it was not possible to calculate yields for these N rates. The SUNDIAL-FRS recommendations were much too high, and only reduced by 20kg N/ha with the spring SMN measurements. WELL_N accurately predicted the optimum. The RB209 recommendation was too low.

Crop N uptake and Soil Mineral N (SMN, nitrate plus ammonium) at harvest (kgN/ha)

N rate*	Crop N uptake	SMN 0-30cm	SMN 30-60cm	SMN 60-90cm	Crop N + SMN
Measured values					
0	73	28	8	7	116
160	207	27	9	6	249
175 (farm) [§]	N/A	6	6	8	N/A
WELL_N Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	123	5	5	5	138
160	219	5	5	5	234
SUNDIAL-FRS Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	46	48	14	9	117
160	183	66	30	9	288
175 (farm) [§]	201	57	23	9	289

* Zero and maximum rates used in trial, plus farm rate[§] where available.

Comments: SUNDIAL-FRS underestimated crop N at zero and overestimated SMN at all N rates. This suggests that the simulated crop could not take up nitrogen as quickly as observed in the field. Implementing the existing variable uptake module of SUNDIAL could solve this problem. WELL_N gave reasonable estimates of SMN but overestimated crop uptake at the zero rate.

APPENDIX B

Site reference: 03b

Year: 1999

Topsoil texture:	Silt loam	Previous crop:	Field peas
Current crop:	Winter wheat	Expected mkt yield t/ha:	11.5
Maximum mkt yield t/ha:	10.6	Maximum total DW t/ha:	15.5

Summary of N recommendations (kgN/ha) and calculated yields (t/ha):

Method	Optimum*	RB209	Farm [§]	WELL_N:				SUNDIAL-FRS:			
				Predictive		Retrospective		Predictive		Retrospective	
				Default weather	Actual weather	Default weather	Actual weather	Default weather	+ spring SMN	Actual weather	+ spring SMN
Recommendation	0 (±6.1)	205	118	75	75	50	75	240	179	200	140
Calculated yield *	10.0	9.0	9.9	10.0	10.0	10.0	10.0	8.4	9.3	9.0	9.7
% difference from optimum yield		-10	-1	0	0	0	0	-16	-7	-10	-3

* Calculated from linear plus exponential curve fitted to trial data. Estimated standard error given in brackets.

§ Farm recommendation is actual rate used by the farmer in the rest of the field.

Comments: Marketable yields declined with increasing levels of applied N above 150 kgN/ha. WELL_N gave good predictive and retrospective recommendations that, although higher than required, did not affect yield. The SUNDIAL-FRS predictive recommendations (based on an expected yield of 11.5 t/ha that was not achieved in the trial) were too high, and gave a yield penalty. The use of spring SMN measurements improved the SUNDIAL recommendations. The SUNDIAL retrospective run with actual weather, a reduced yield (10.0 t/ha) and spring SMN, reduced the recommendation further to 140 kg N/ha. This was still too high, but did not incur a yield penalty. The RB209 recommendation was also too high.

Crop N uptake and Soil Mineral N (SMN, nitrate plus ammonium) at harvest (kgN/ha)

N rate*	Crop N uptake	SMN 0-30cm	SMN 30-60cm	SMN 60-90cm	Crop N + SMN
Measured values					
0	162	20	14	7	203
250	244	48	23	9	324
118 [§]	196	31	18	11	256
WELL_N Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	174	17	7	6	204
250	265	42	56	40	403
SUNDIAL-FRS Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	116	20	11	9	157
250	202	142	18	9	371
118 [§]	227	21	11	9	268

* Zero and maximum rates used in trial, plus farm rate [§] where available.

Comments: WELL_N gave a good estimate of crop N at both zero and maximum rates, but overestimated SMN at the maximum N rate. SUNDIAL underestimated crop N at both zero and maximum rates, resulting in an accumulation of SMN at the maximum N rate. Again, these results suggest implementation of the variable uptake module in SUNDIAL-FRS would improve the simulations.

APPENDIX B

Site reference: 04

Year: 1998

Topsoil texture:	Silt loam	Previous crop:	Winter wheat
Current crop:	Winter wheat	Expected mkt yield t/ha:	9.0
Maximum mkt yield t/ha:	8.0	Maximum total DW t/ha:	11.5

Summary of N recommendations (kgN/ha) and calculated yields (t/ha):

Method	Optimum*	RB209	Farm [§]	WELL_N:				SUNDIAL-FRS:			
				Predictive		Retrospective		Predictive		Retrospective	
				Default weather	Actual weather	Default weather	Actual weather	Default weather	+ spring SMN	Actual weather	+ spring SMN
Recommendation	See below	180	264	100	150	75	125	230	230	210	210
Calculated yield *	N/A										
% difference from optimum yield											

* Calculated from linear plus exponential curve fitted to trial data.

[§] Farm recommendation is actual rate used by the farmer in the rest of the field.

Comments: There was a linear response to applied N and no optimum could be fitted. It was not possible to derive yields. The expected yield of 9 t/ha was not achieved, even by the farm rate, which was adjusted to increase grain protein. The expected yield may have been unrealistic for this site in this year. However, the trial received only a single dose of N in contrast to farm practice (3 applications) and timing may have been crucial for this variety.

The SUNDIAL-FRS predictive recommendation was unaffected by SMN measurements. The retrospective recommendation used the maximum yield of 8.0 t/ha, which reduced the recommendation a little. WELL_N recommendations appear to be low and affected by both the high yield expectation and actual weather.

Crop N uptake and Soil Mineral N (SMN, nitrate plus ammonium) at harvest (kgN/ha)

N rate*	Crop N uptake	SMN 0-30cm	SMN 30-60cm	SMN 60-90cm	Crop N + SMN
Measured values					
0	106	66	21	13	206
220	174	147	38	28	387
264 (farm) [§]	N/A	70	65	77	
WELL_N Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	93	4	22	7	126
220	211	22	15	28	276
SUNDIAL-FRS Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	131	33	16	9	189
220	149	28	140	9	326
264 (farm) [§]					

* Zero and maximum rates used in trial, plus farm rate[§] where available.

Comments: The SUNDIAL-FRS simulations were reasonable, although the distribution within the 0-60 cm soil layers was not well simulated at the maximum N rate (compare sites 1/99 and 2/98). WELL_N considerably underestimated SMN.

APPENDIX B

Site reference: **04**

Year: **1999**

Topsoil texture:	Silt loam	Previous crop:	Winter wheat
Current crop:	Winter OSR	Expected mkt yield t/ha:	4.0
Maximum mkt yield t/ha:	3.1	Maximum total DW t/ha:	10.6

Summary of N recommendations (kgN/ha) and calculated yields (t/ha):

Method	Optimum*	RB209	Farm [§]	WELL_N:				SUNDIAL-FRS:			
				Predictive		Retrospective		Predictive		Retrospective	
				Default weather	Actual weather	Default weather	Actual weather	Default weather	+ spring SMN	Actual weather	+ spring SMN
Recommendation	0	250	110	N/A	N/A	N/A	N/A	0	0	0	0
Calculated yield *	1.9	1.9	1.9					1.9	1.9	1.9	1.9
% difference from optimum yield											

* Calculated as mean trial yield, as there was no significant response to N within the range of the trial.

§ Farm recommendation is actual rate used by the farmer in the rest of the field.

Comments: There was no significant response to applied N at this site. SUNDIAL-FRS correctly recommends that no fertiliser N should be applied. The expected yield is not achieved; the maximum yield of 3.1 t/ha is due to one very high yielding plot, all other plots yielding around 2 t/ha. The SUNDIAL-FRS recommendation would not have achieved the expected yield. The RB209 recommendation (which included 30 kgN/ha in the autumn) was too high.

WELL_N is not parameterised for winter OSR.

Crop N uptake and Soil Mineral N (SMN, nitrate plus ammonium) at harvest (kgN/ha)

N rate*	Crop N uptake	SMN 0-30cm	SMN 30-60cm	SMN 60-90cm	Crop N + SMN
Measured values					
0	102	40	17	11	170
300	121	171	24	14	330
110 (farm) [§]	101	130	74	73	378
WELL_N Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	N/A	N/A	N/A	N/A	
300	N/A	N/A	N/A	N/A	
SUNDIAL-FRS Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	95	45	26	9	175
300	85	66	291	13	455
110 (farm) [§]	76	43	123	15	257

* Zero and maximum rates used in trial, plus farm rate[§] where available.

Comments: Note the very large SMN values when fertiliser N was applied. SUNDIAL-FRS overestimates this at the maximum N rate. SUNDIAL-FRS does not simulate the slight increase in crop N uptake due to luxury uptake.

APPENDIX B

Site reference: 05

Year: 1998

Topsoil texture:	Sandy loam	Previous crop:	Field peas
Current crop:	Winter wheat	Expected mkt yield t/ha:	8.5
Maximum mkt yield t/ha:	8.0	Maximum total DW t/ha:	15.2

Summary of N recommendations (kgN/ha) and calculated yields (t/ha):

Method	Optimum*	RB209	Farm [§]	WELL_N:				SUNDIAL-FRS:			
				Predictive		Retrospective		Predictive		Retrospective	
				Default weather	Actual weather	Default weather	Actual weather	Default weather	+ spring SMN	Actual weather	+ spring SMN
Recommendation	142	180	180	100	150	100	150	180	100	160	60
Calculated yield *	7.6	7.5	7.5	7.1	7.6	7.1	7.6	7.5	7.1	7.6	6.5
% difference from optimum yield		-1	-1	-6	1	-6	1	-1	-6	0	-15

* Calculated from linear plus exponential curve fitted to trial data.

§ Farm recommendation is actual rate used by the farmer in the rest of the field.

Comments: SUNDIAL-FRS gave good predictive recommendations, within 6% of the calculated yield of the optimum. The retrospective simulation was run with the lower expected yield of 7.6 t/ha, which improved the recommendation further. However, including spring SMN reduced the retrospective recommendation by 100 kgN/ha, with a dramatic effect on yields. WELL_N predictions were slightly low but corrected by using actual weather.

Crop N uptake and Soil Mineral N (SMN, nitrate plus ammonium) at harvest (kgN/ha)

N rate*	Crop N uptake	SMN 0-30cm	SMN 30-60cm	SMN 60-90cm	Crop N + SMN
Measured values					
0	100	97	33	18	241
210	214	154	81	50	482
222 (farm) [§]	N/A	132	59	29	
WELL_N Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	103	11	6	14	134
210	223	11	6	17	223
SUNDIAL-FRS Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	114	18	12	9	153
210	132	68	126	24	350
222 (farm) [§]	196	66	100	9	370

* Zero and maximum rates used in trial, plus farm rate[§] where available.

Comments: SUNDIAL-FRS simulated crop N well at the zero N rate but underestimated SMN. Crop N uptake was underestimated at the maximum N rate, and again too much SMN was present in the 30-60cm soil layer, although total SMN was reasonable. WELL_N simulated crop N well but considerably underestimated SMN.

APPENDIX B

Site reference: 05

Year: 1999

Topsoil texture:	Sandy loam	Previous crop:	Winter wheat
Current crop:	Winter wheat	Expected mkt yield t/ha:	5.5
Maximum mkt yield t/ha:	4.1	Maximum total DW t/ha:	9.0

Summary of N recommendations (kgN/ha) and calculated yields (t/ha):

Method	Optimum*	RB209	Farm [§]	WELL_N:				SUNDIAL-FRS:			
				Predictive		Retrospective		Predictive		Retrospective	
				Default weather	Actual weather	Default weather	Actual weather	Default weather	+ spring SMN	Actual weather	+ spring SMN
Recommendation	20	210	125	50	100	50	100	140	60	80	0
Calculated yield *	3.8	3.6	3.7	3.8	3.8	3.8	3.7	3.7	3.8	3.7	2.6
% difference from optimum yield		-6	-3	0	-2	0	-2	-4	-1	-2	-32

* Calculated from linear plus exponential curve fitted to trial data.

§ Farm recommendation is actual rate used by the farmer in the rest of the field.

Comments: Yields were reduced and variable due to blackgrass infestation. This was partially allowed for in the low expected yield so that SUNDIAL-FRS and WELL_N recommendations were closer to the optimum than the RB209 or farm rate. The SUNDIAL retrospective recommendation used a yield of 3.8 t/ha. The use of SMN improved the SUNDIAL retrospective recommendation, to within 20 kgN/ha of the field optimum, but was calculated to reduce yield substantially.

Crop N uptake and Soil Mineral N (SMN, nitrate plus ammonium) at harvest (kgN/ha)

N rate*	Crop N uptake	SMN 0-30cm	SMN 30-60cm	SMN 60-90cm	Crop N + SMN
Measured values					
0	45	46	34	23	148
250	116	75	78	70	339
125 (farm) [§]	106	44	26	24	200
WELL_N Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	109	5	5	19	138
250	188	42	59	39	328
SUNDIAL-FRS Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	49	36	17	13	114
250(max)	75	87	154	9	325
125(farm) [§]	73	64	54	9	200

* Zero and maximum rates used in trial, plus farm rate[§] where available.

Comments: SUNDIAL-FRS underestimated crop N at the higher N rates, and accumulated SMN. WELL_N overestimated N uptake but underestimated soil N content so that crop + soil N estimates were reasonable.

APPENDIX B

Site reference: 06a

Year: 1998

Topsoil texture:	Clay loam	Previous crop:	Winter wheat
Current crop:	Potatoes	Expected mkt yield t/ha:	40
Maximum mkt yield t/ha:	46.8	Maximum total DW t/ha:	12.0

Summary of N recommendations (kgN/ha) and calculated yields (t/ha):

Method	Optimum*	RB209	Farm [§]	WELL_N:				SUNDIAL-FRS:			
				Predictive		Retrospective		Predictive		Retrospective	
				Default weather	Actual weather	Default weather	Actual weather	Default weather	+ spring SMN	Actual weather	+ spring SMN
Recommendation	See below	220	240	150	150	175	175	220	220	220	220
Calculated yield *	N/A	45.7	46.3	43.5	43.5	44.3	44.3	45.7	45.7	45.7	45.7
% difference from optimum yield											

* Calculated from linear plus exponential curve fitted to trial data.

§ Farm recommendation is actual rate used by the farmer in the rest of the field.

Comments: No optimum could be fitted. Note the very similar crop N uptakes and SMN values at the zero and maximum N rates. The low response to N is not unexpected in this potato variety. Potato responses to N depend heavily on the variety with determinate and indeterminate varieties showing different responses. The SUNDIAL-FRS recommendation was very close to the farm and RB209 recommendations, and was not affected by spring SMN or actual weather. Simulated leaching losses were very high (148kg N/ha) before the 1998 fertiliser was applied. Simulated spring SMN (mid February) values were within 5 kg N/ha of the measured values. The distribution of N rates used in the trial make it difficult to judge the accuracy of the WELL_N recommendation. Used predictively, WELL_N was affected by the higher than expected marketable yield.

Crop N uptake and Soil Mineral N (SMN, nitrate plus ammonium) at harvest (kgN/ha)

N rate*	Crop N uptake	SMN 0-30cm	SMN 30-60cm	SMN 60-90cm	Crop N + SMN
Measured values					
0	96	42	56	N/A	194
250	112	49	62	N/A	223
240 (farm) [§]	N/A	N/A	N/A		
WELL_N Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	96	14	14	N/A	124
250	218	14	14	N/A	246
SUNDIAL-FRS Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	60	11	12	N/A	83
250	178	16	86	N/A	280
240 (farm) [§]					

* Zero and maximum rates used in trial, plus farm rate[§] where available.

Comments: The soil reaches limestone at 60cm, so no samples were taken below this depth. SUNDIAL-FRS gave a poor simulation of crop N and SMN at harvest at this site. Refer to comments above concerning variation in potato response to N according to variety. WELL_N underestimated SMN at both rates and overestimated uptake at the maximum rate.

APPENDIX B

Site reference: 06b

Year: 1999

Topsoil texture:	Clay loam	Previous crop:	Field peas
Current crop:	Winter wheat	Expected mkt yield t/ha:	7.5
Maximum mkt yield t/ha:	10.7	Maximum total DW t/ha:	21.5

Summary of N recommendations (kgN/ha) and calculated yields (t/ha):

Method	Optimum*	RB209	Farm [§]	WELL_N:				SUNDIAL-FRS:			
				Predictive		Retrospective		Predictive		Retrospective	
				Default weather	Actual weather	Default weather	Actual weather	Default weather	+ spring SMN	Actual weather	+ spring SMN
Recommendation	157 (±4.3)	207	190	125	100	175	175	160	141	200	181
Calculated yield *	10.4	10.6	10.6	10.0	9.4	10.6	10.6	10.4	10.2	10.6	10.6
% difference from optimum yield		2	2	-4	-10	2	2	0	-2	2	2

* Calculated from linear plus exponential curve fitted to trial data. Estimated standard error given in brackets.

§ Farm recommendation is actual rate used by the farmer in the rest of the field.

Comments: Predictive SUNDIAL-FRS recommendations were within 20 kg N/ha of the optimum. Used retrospectively, with a revised yield of 10.4 t/ha, the recommendations were increased, but with SMN within 25 kgN/ha of the optimum. WELL_N used predictively underestimated N requirement because the expected marketable yield on which it was based was 40% less than the achieved yield. Used retrospectively WELL_N gave a good recommendation without loss of yield. The RB209 recommendation was too high.

Crop N uptake and Soil Mineral N (SMN, nitrate plus ammonium) at harvest (kgN/ha)

N rate*	Crop N uptake	SMN 0-30cm	SMN 30-60cm	SMN 60-90cm	Crop N + SMN
Measured values					
0	59	55	N/A	N/A	
250	282	57	N/A	N/A	
190 (farm) [§]	254	45	N/A	N/A	
WELL_N Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	123	11			
250	275	11			
SUNDIAL-FRS Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	68	26			
250	268	27			
190 (farm) [§]					

* Zero and maximum rates used in trial, plus farm rate[§] where available.

Comments: There was good agreement between measured and simulated crop N values at harvest with SUNDIAL-FRS. WELL_N overestimated crop N uptake at zero. Due to soil samples being taken only to 30 cm, SMN data was insufficient to make other comparisons.

APPENDIX B

Site reference: 07

Year: 1998

Topsoil texture:	Clay loam	Previous crop:	Winter wheat
Current crop:	Winter OSR	Expected mkt yield t/ha:	2.9
Maximum mkt yield t/ha:	4.0	Maximum total DW t/ha:	6.8

Summary of N recommendations (kgN/ha) and calculated yields (t/ha):

Method	Optimum*	RB209	Farm [§]	WELL_N:				SUNDIAL-FRS:			
				Predictive		Retrospective		Predictive		Retrospective	
				Default weather	Actual weather	Default weather	Actual weather	Default weather	+ spring SMN	Actual weather	+ spring SMN
Recommendation	See below	190	140	N/A	N/A	N/A	N/A	184	184	184	184
Calculated yield *	N/A										
% difference from optimum yield											

* Calculated from linear plus exponential curve fitted to trial data.

§ Farm recommendation is actual rate used by the farmer in the rest of the field.

Comments: There was a linear response to applied N and no optimum could be fitted. The trial data was very variable. No yields could be calculated. The maximum marketable yield was much higher than the expected yield of 2.9 t/ha. The SUNDIAL-FRS recommendation, based on the expected yield, was within 50kgN/ha of the farm rate, which gave a yield of 2.9t/ha in the remainder of the field, suggesting that SUNDIAL-FRS gave a reasonable recommendation for this yield

WELL_N is not parameterised for winter OSR.

Crop N uptake and Soil Mineral N (SMN, nitrate plus ammonium) at harvest (kgN/ha)

N rate*	Crop N uptake	SMN 0-30cm	SMN 30-60cm	SMN 60-90cm	Crop N + SMN
Measured values					
0	65	38	21	10	134
275	154	98	32	16	300
140 (farm) [§]	N/A	N/A	N/A	N/A	N/A
WELL_N Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	N/A	N/A	N/A	N/A	
275	N/A	N/A	N/A	N/A	
SUNDIAL-FRS Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	44	13	13	11	81
275	146	43	51	11	251
140 (farm) [§]					

* Zero and maximum rates used in trial, plus farm rate[§] where available.

Comments: SUNDIAL-FRS gave a reasonable estimation of crop N uptake and slightly underestimated SMN at the maximum N rate.

APPENDIX B

Site reference: 07

Year: 1999

Topsoil texture:	Clay loam	Previous crop:	Winter OSR
Current crop:	Winter wheat	Expected mkt yield t/ha:	10.5
Maximum mkt yield t/ha:	9.7	Maximum total DW t/ha:	16.9

Summary of N recommendations (kgN/ha) and calculated yields (t/ha):

Method	Optimum*	RB209	Farm [§]	WELL_N:				SUNDIAL-FRS:			
				Predictive		Retrospective		Predictive		Retrospective	
				Default weather	Actual weather	Default weather	Actual weather	Default weather	+ spring SMN	Actual weather	+ spring SMN
Recommendation	See below	160	215	100	100	100	100	160	180	160	180
Calculated yield *	N/A	8.7	9.3	8.2	8.2	8.2	8.2	8.7	8.9	8.7	8.9
% difference from optimum yield											

* Calculated from linear plus exponential curve fitted to trial data.

§ Farm recommendation is actual rate used by the farmer in the rest of the field.

Comments: It was not possible to derive an optimum or to calculate yields at the optimum, as the optimum was above the maximum N rate used. The SUNDIAL-FRS, WELL_N and RB209 recommendations were probably too low, and were unlikely to have achieved the expected yield.

Crop N uptake and Soil Mineral N (SMN, nitrate plus ammonium) at harvest (kgN/ha)

N rate*	Crop N uptake	SMN 0-30cm	SMN 30-60cm	SMN 60-90cm	Crop N + SMN
Measured values					
0	98	41	24	16	179
250	286	36	36	19	377
215 (farm) [§]	182	49	27	12	270
WELL_N Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	145	16	7	6	174
250	284	14	6	26	330
SUNDIAL-FRS Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	95	12	19	11	137
250	233	28	130	11	402
215 (farm) [§]	201	28	127	11	367

* Zero and maximum rates used in trial, plus farm rate[§] where available.

Comments: SUNDIAL-FRS overestimated SMN in the 30-60 cm layer at the high N rates. This may be due to immobilization of nitrogen by organic residues in the soil. Simulations of immobilization in this soil would be improved by the development of field diagnostics to describe the quantity and quality of soil organic matter in the soil profile. WELL_N tended to underestimate N in the soil.

APPENDIX B

Site reference: 08

Year: 1998

Topsoil texture:	Clay loam	Previous crop:	Field pea
Current crop:	Winter wheat	Expected mkt yield t/ha:	9.5
Maximum mkt yield t/ha:	6.4	Maximum total DW t/ha:	13.5

Summary of N recommendations (kgN/ha) and calculated yields (t/ha):

Method	Optimum*	RB209	Farm [§]	WELL_N:				SUNDIAL-FRS:			
				Predictive		Retrospective		Predictive		Retrospective	
				Default weather	Actual weather	Default weather	Actual weather	Default weather	+ spring SMN	Actual weather	+ spring SMN
Recommendation	0	180	160	50	75	50	75	200	100	160	60
Calculated yield *	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9
% difference from optimum yield											

* Calculated as mean trial yield, as there was no significant response to N within the range of the trial.

§ Farm recommendation is actual rate used by the farmer in the rest of the field.

Comments: There was no significant response to applied N in the field trials. The maximum trial yield was well below the expected yield, but the yield achieved with the farm rate in the remainder of the field (9.0 t/ha) was close to the expected yield. This implies that the timing of the N applications was very important. The SUNDIAL predictive rates were well above the optimum, but when run with a revised yield of 6.9 t/ha, actual weather and spring SMN, the rate was reduced substantially. WELL_N gave slightly high predictive and retrospective recommendations, which increased using actual weather data.

Crop N uptake and Soil Mineral N (SMN, nitrate plus ammonium) at harvest (kgN/ha)

N rate*	Crop N uptake	SMN 0-30cm	SMN 30-60cm	SMN 60-90cm	Crop N + SMN
Measured values					
0	106	34	12	11	163
235	167	138	23	12	340
160 [§]	N/A	N/A	N/A	N/A	
WELL_N Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	146	8	6	5	165
235	247	27	46	16	336
SUNDIAL-FRS Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	39	17	24	11	91
235	129	29	28	11	196
160 [§]	193	15	20	11	239

* Zero and maximum rates used in trial, plus farm rate[§] where available.

Comments: SUNDIAL-FRS underestimated both crop N and SMN. WELL_N overestimated crop N and underestimated soil N 0-30 cm at the maximum rate.

APPENDIX B

Site reference: 08

Year: 1999

Topsoil texture:	Clay loam	Previous crop:	Winter wheat
Current crop:	Winter barley	Expected mkt yield t/ha:	7.5
Maximum mkt yield t/ha:	6.4	Maximum total DW t/ha:	9.4

Summary of N recommendations (kgN/ha) and calculated yields (t/ha):

Method	Optimum*	RB209	Farm [§]	WELL_N:				SUNDIAL-FRS:			
				Predictive		Retrospective		Predictive		Retrospective	
				Default weather	Actual weather	Default weather	Actual weather	Default weather	+ spring SMN	Actual weather	+ spring SMN
Recommendation	53	160	160	100	125	50	100	80	0	60	0
Calculated yield *	6.1	6.2	6.2	6.2	6.2	6.1	6.2	6.2	4.6	6.2	4.6
% difference from optimum yield		1	1	1	1	0	1	1	-25	1	-25

* Calculated from linear plus exponential curve fitted to trial data.

§ Farm recommendation is actual rate used by the farmer in the rest of the field.

Comments: SUNDIAL-FRS gave a good predictive recommendation. Including spring SMN values gave a slightly worse recommendation, which resulted in a big yield penalty. WELL_N tended to overestimate the requirement, but without effecting yield.

Crop N uptake and Soil Mineral N (SMN, nitrate plus ammonium) at harvest (kgN/ha)

N rate*	Crop N uptake	SMN 0-30cm	SMN 30-60cm	SMN 60-90cm	Crop N + SMN
Measured values					
0	66	39	14	15	134
250	136	47	19	22	224
160 (farm) [§]	124	30	18	16	224
WELL_N Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	114	16	7	11	148
250	192	73	38	37	320
SUNDIAL-FRS Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	84	17	32	31	164
250	121	17	160	80	378
160 (farm) [§]	105	18	119	73	315

* Zero and maximum rates used in trial, plus farm rate[§] where available.

Comments: SUNDIAL-FRS simulated crop N uptake well at both N rates, and SMN at harvest well, when no fertilizer N was applied, but over estimated SMN where N was applied by over 150 kgN/ha. WELL_N simulated crop + soil N well at zero N, but overestimated crop N and soil N in the 0-60cm layer at the maximum N rate.

APPENDIX B

Site reference: 09

Year: 1998

Topsoil texture:	Sandy clay loam	Previous crop:	Spring OSR
Current crop:	Winter wheat	Expected mkt yield t/ha:	9.0
Maximum mkt yield t/ha:	10.8	Maximum total DW t/ha:	15.5

Summary of N recommendations (kgN/ha) and calculated yields (t/ha):

Method	Optimum*	RB209	Farm [§]	WELL_N:				SUNDIAL-FRS:			
				Predictive		Retrospective		Predictive		Retrospective	
				Default weather	Actual weather	Default weather	Actual weather	Default weather	+ spring SMN	Actual weather	+ spring SMN
Recommendation	70 (±6.8)	170	122	75	125	75	125	240	160	280	180
Calculated yield *	10.3	9.3	10.2	10.3	10.2	10.3	10.2	6.5	9.5	4.3	9.0
% difference from optimum yield		-10	-1	0	-1	0	-1	-36	-7	-58	-13

* Calculated from linear plus exponential curve fitted to trial data. Estimated standard error given in brackets.

§ Farm recommendation is actual rate used by the farmer in the rest of the field.

Comments: SUNDIAL-FRS overestimated the recommendation. Including spring SMN measurements improved the recommendation, with estimated yields within 7% of those calculated for the optimum. The retrospective recommendations, based on a yield of 10.3 t/ha, were higher. WELL_N gave good predictive and retrospective recommendations with default weather but were slightly higher with actual weather although on a par with RB209 and farm practice.

Crop N uptake and Soil Mineral N (SMN, nitrate plus ammonium) at harvest (kgN/ha)

N rate*	Crop N uptake	SMN 0-30cm	SMN 30-60cm	SMN 60-90cm	Crop N + SMN
Measured values					
0	126	66	15	16	223
170	223	92	21	15	351
122(farm) [§]	N/A	22	31	30	
WELL_N Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	131	11	6	6	154
170	233	11	6	6	275
SUNDIAL-FRS Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	94	18	11	9	132
170	221	22	11	9	263
122 (farm) [§]		18	12	9	

* Zero and maximum rates used in trial, plus farm rate[§] where available.

Comments: Both WELL_N and SUNDIAL underestimated SMN at 0-30cm, but simulated crop N uptake well.

APPENDIX B

Site reference: 09

Year: 1999

Topsoil texture:	Sandy clay loam	Previous crop:	Winter wheat
Current crop:	Spring OSR	Expected mkt yield t/ha:	2.8
Maximum mkt yield t/ha:	3.4	Maximum total DW t/ha:	9.8

Summary of N recommendations (kgN/ha) and calculated yields (t/ha):

Method	Optimum*	RB209	Farm [§]	WELL_N:				SUNDIAL-FRS:			
				Predictive		Retrospective		Predictive		Retrospective	
				Default weather	Actual weather	Default weather	Actual weather	Default weather	+ spring SMN	Actual weather	+ spring SMN
Recommendation	0	120	115	N/A	N/A	N/A	N/A	100	0	100	0
Calculated yield *	3.2	3.2	3.2					3.2	3.2	3.2	3.2
% difference from optimum yield											

* Calculated as mean trial yield, as there was no significant response to N within the range of the trial.

§ Farm recommendation is actual rate used by the farmer in the rest of the field.

Comments: There was no significant response to N in this trial. The trial area received an application of slurry by a neighbouring farmer in January 1999, the quantity was unknown. The spring SMN values, consequently, were extremely high. The initial SUNDIAL-FRS recommendation was correctly reduced to 0 when spring SMN measurements were included.

WELL_N is not parameterised for oil seed rape.

Crop N uptake and Soil Mineral N (SMN, nitrate plus ammonium) at harvest (kgN/ha)

N rate*	Crop N uptake	SMN 0-30cm	SMN 30-60cm	SMN 60-90cm	Crop N + SMN
Measured values					
0	146	61	30	15	252
(max)	171	62	52	21	306
(farm) [§]	122	53	38	16	229
WELL_N Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	N/A	N/A	N/A	N/A	
(max)	N/A	N/A	N/A	N/A	
SUNDIAL-FRS Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	N/A	N/A	N/A	N/A	
(max)	N/A	N/A	N/A	N/A	
(farm) [§]					

* Zero and maximum rates used in trial, plus farm rate[§] where available.

Comments: It was not possible to simulate crop N uptake and SMN, as the amount of slurry applied in the winter was unknown.

APPENDIX B

Site reference: 10

Year: 1998

Topsoil texture:	Clay loam	Previous crop:	Field peas
Current crop:	Winter wheat	Expected mkt yield t/ha:	7.5
Maximum mkt yield t/ha:	9.3	Maximum total DW t/ha:	15.4

Summary of N recommendations (kgN/ha) and calculated yields (t/ha):

Method	Optimum*	RB209	Farm [§]	WELL_N:				SUNDIAL-FRS:			
				Predictive		Retrospective		Predictive		Retrospective	
				Default weather	Actual weather	Default weather	Actual weather	Default weather	+ spring SMN	Actual weather	+ spring SMN
Recommendation	50	207	190	75	100	100	100	139	119	162	141
Calculated yield *	9.2	7.9	8.1	9.1	8.9	8.9	8.9	8.5	8.7	8.4	8.5
% difference from optimum yield		-14	-12	-1	-3	-3	-3	-7	-5	-9	-7

* Calculated from linear plus exponential curve fitted to trial data.

§ Farm recommendation is actual rate used by the farmer in the rest of the field.

Comments: RB209 and farm practice overestimated the requirement, leading to >10% loss in yield. SUNDIAL also gave rather high recommendations, although the calculated yield of the best was within 5% of the calculated yield at the optimum N rate. Spring SMN values slightly reduced the SUNDIAL-FRS recommendations. The retrospective recommendation, using a yield of 9.2 t/ha, gave higher recommendations. WELL_N gave slightly high recommendations but within 3% of the optimum yield. Both models were considerably better than RB209 and farm practice.

Crop N uptake and Soil Mineral N (SMN, nitrate plus ammonium) at harvest (kgN/ha)

N rate*	Crop N uptake	SMN 0-30cm	SMN 30-60cm	SMN 60-90cm	Crop N + SMN
Measured values					
0	N/A	21	N/A	N/A	
250	N/A	14	N/A	N/A	
190 (farm) [§]	N/A	17	N/A	N/A	
WELL_N Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	124	20			
250	250	20			
SUNDIAL-FRS Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	99	14			
250	179	33			
190 (farm) [§]	170	33			

* Zero and maximum rates used in trial, plus farm rate[§] where available.

Comments: It is not possible to draw any conclusions about the simulated crop and SMN values at harvest as insufficient measurements were made.

APPENDIX B

Site reference: 10

Year: 1999

Topsoil texture:	Clay loam	Previous crop:	Winter wheat
Current crop:	Potatoes	Expected mkt yield t/ha:	60
Maximum mkt yield t/ha:	82	Maximum total DW t/ha:	22.3

Summary of N recommendations (kgN/ha) and calculated yields (t/ha):

Method	Optimum*	RB209	Farm [§]	WELL_N:				SUNDIAL-FRS:			
				Predictive		Retrospective		Predictive		Retrospective	
				Default weather	Actual weather	Default weather	Actual weather	Default weather	+ spring SMN	Actual weather	+ spring SMN
Recommendation	221 (±12)	240	213	175	200	250	275	240	200	520	480
Calculated yield *	76	77	75	71	74	77	75	77	74	N/A	N/A
% difference from optimum yield		1	-1	-7	-3	2	3	2	-2		

* Calculated from linear plus exponential curve fitted to trial data. Estimated standard error given in brackets.

§ Farm recommendation is actual rate used by the farmer in the rest of the field.

Comments: The SUNDIAL-FRS predictive recommendation agreed with the optimum obtained from the field trial, although it was using an expected yield of only 60 t/ha. The retrospective recommendation, using an expected yield of 89 t/ha, gave recommendations that were far too high and outside the range of the trial. WELL_N gave a low recommendation when used predictively due to the expected yield being 27% less than the actual maximum.

Crop N uptake and Soil Mineral N (SMN, nitrate plus ammonium) at harvest (kgN/ha)

N rate*	Crop N uptake	SMN 0-30cm	SMN 30-60cm	SMN 60-90cm	Crop N + SMN
Measured values					
0	157	28	N/A	N/A	186
300	220	49	N/A	N/A	269
213 (farm) [§]	N/A	N/A	N/A	N/A	
WELL_N Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	124	14			138
300	232	30			262
SUNDIAL-FRS Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	102	11			112
300	360	11			371
213 (farm) [§]	219	11			229

* Zero and maximum rates used in trial, plus farm rate[§] where available.

Comments: SUNDIAL-FRS did not simulate crop N or SMN at harvest well. WELL_N gave a good simulation at the maximum N rate.

APPENDIX B

Site reference: 11

Year: 1998

Topsoil texture:	Clay	Previous crop:	Winter OSR
Current crop:	Winter wheat	Expected mkt yield t/ha:	10.0
Maximum mkt yield t/ha:	8.8	Maximum total DW t/ha:	15.5

Summary of N recommendations (kgN/ha) and calculated yields (t/ha):

Method	Optimum*	RB209	Farm [§]	WELL_N:				SUNDIAL-FRS:			
				Predictive		Retrospective		Predictive		Retrospective	
				Default weather	Actual weather	Default weather	Actual weather	Default weather	+ spring SMN	Actual weather	+ spring SMN
Recommendation	199	150	200	75	100	50	100	280	240	118	180
Calculated yield *	8.4	7.8	8.4	6.6	7.0	6.2	7.0	N/A	N/A	7.3	8.2
% difference from optimum yield		-7	0	-21	-16	-26	-16			-12.6	-1.6

* Calculated from linear plus exponential curve fitted to trial data.

§ Farm recommendation is actual rate used by the farmer in the rest of the field.

Comments: The predictive SUNDIAL-FRS recommendation was much higher than the optimum, although improved slightly by including spring SMN. Yields were not calculated for the SUNDIAL-FRS predictive recommendations, as they were outside the range of N rates applied in the trial. The SUNDIAL retrospective recommendations, based on a yield of 8.4 t/ha, were reduced to 180 kg N/ha (with actual weather and spring SMN), within 20 kg N/ha of the optimum. Without spring SMN, simulated crop uptake was only 49% of the N requirement, which reduced the recommendation and the yield.

WELL_N is not parameterised for heavy clay soils. The recommended rates and yields were below the calculated optimum.

Crop N uptake and Soil Mineral N (SMN, nitrate plus ammonium) at harvest (kgN/ha)

N rate*	Crop N uptake	SMN 0-30cm	SMN 30-60cm	SMN 60-90cm	Crop N + SMN
Measured values					
0	80	35	20	10	145
220	218	65	23	13	308
200 (farm) [§]	N/A	39	18	15	
WELL_N Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	145	14	6	11	176
220	265	14	19	25	298
SUNDIAL-FRS Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	46	21	17	11	95
220	166	24	56	11	252
200 (farm) [§]					

* Zero and maximum rates used in trial, plus farm rate[§] where available.

Comments: SUNDIAL-FRS underestimated crop N at both N rates, but gave a reasonable estimation of total SMN, except for the distribution of N within the profile at the maximum N rate. WELL_N overestimated crop N at both N rates and underestimated SMN, but total crop N + SMN were well simulated.

APPENDIX B

Site reference: 11

Year: 1999

Topsoil texture:	Clay	Previous crop:	Winter wheat
Current crop:	Winter wheat	Expected mkt yield t/ha:	9.3
Maximum mkt yield t/ha:	11.4	Maximum total DW t/ha:	15.2

Summary of N recommendations (kgN/ha) and calculated yields (t/ha):

Method	Optimum*	RB209	Farm [§]	WELL_N:				SUNDIAL-FRS:			
				Predictive		Retrospective		Predictive		Retrospective	
				Default weather	Actual weather	Default weather	Actual weather	Default weather	+ spring SMN	Actual weather	+ spring SMN
Recommendation	188 (±25.2)	210	236	75	75	125	100	220	100	260	140
Calculated yield *	10.8	11.0	11.1	8.4	8.4	9.8	9.2	11.0	9.2	11.2	10.1
% difference from optimum yield		2	3	-22	-22	-9	-15	2	-15	3	-6

* Calculated from linear plus exponential curve fitted to trial data. Estimated standard error given in brackets.

§ Farm recommendation is actual rate used by the farmer in the rest of the field.

Comments: The predictive SUNDIAL-FRS recommendation was within 40 kg N/ha of the optimum. The retrospective SUNDIAL-FRS recommendation, based on a higher yield of 10.8 t/ha, was 40 kgN/ha more. Including spring SMN measurements reduced the recommendation by 120 kgN/ha, resulting in a yield penalty.

WELL_N is not parameterised for heavy clay soils. Recommended rates and yields were lower than for the calculated optimum, especially when used predictively with the low expected yield.

Crop N uptake and Soil Mineral N (SMN, nitrate plus ammonium) at harvest (kgN/ha)

N rate*	Crop N uptake	SMN 0-30cm	SMN 30-60cm	SMN 60-90cm	Crop N + SMN
Measured values					
0	59	45	21	4	129
250	231	60	29	2	322
236 (farm) [§]	192	41	18	16	267
WELL_N Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	145	14	6	11	176
250	265	14	19	25	323
SUNDIAL-FRS Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	97	26	48	22	193
250	278	31	74	20	403
236 (farm) [§]	271	30	54	16	371

* Zero and maximum rates used in trial, plus farm rate[§] where available.

Comments: SUNDIAL-FRS and WELL_N overestimated crop N and SMN at harvest. The variable N uptake module should be implemented in SUNDIAL-FRS. WELL_N overestimated crop N uptake at the zero N rate.

APPENDIX B

Site reference: 12

Year: 1998

Topsoil texture:	Clay	Previous crop:	Winter wheat
Current crop:	Winter wheat	Expected mkt yield t/ha:	8.55
Maximum mkt yield t/ha:	9.5	Maximum total DW t/ha:	14.7

Summary of N recommendations (kgN/ha) and calculated yields (t/ha):

Method	Optimum*	RB209	Farm [§]	WELL_N:				SUNDIAL-FRS:			
				Predictive		Retrospective		Predictive		Retrospective	
				Default weather	Actual weather	Default weather	Actual weather	Default weather	+ spring SMN	Actual weather	+ spring SMN
Recommendation	121	200	223	100	125	100	125	202	160	202	202
Calculated yield *	8.5	9.0	9.1	8.3	8.6	8.3	8.6	9.0	8.8	9.0	9.0
% difference from optimum yield		5	7	-3	0	-3	0	5	3	5	5

* Calculated from linear plus exponential curve fitted to trial data.

§ Farm recommendation is actual rate used by the farmer in the rest of the field.

Comments: The recommendations given by both SUNDIAL-FRS and RB209 are too high. SUNDIAL-FRS recommended 80 kgN/ha more than the optimum, yet the calculated yield was within 6% of the optimum, due to the relatively small response of yield to N. The use of spring SMN measurements improved the recommendation to within 40 kg of the optimum, for the predictive recommendation only.

WELL_N is not parameterised for heavy clay soils, but nevertheless gave recommendations within 25 kg of the optimum.

Crop N uptake and Soil Mineral N (SMN, nitrate plus ammonium) at harvest (kgN/ha)

N rate*	Crop N uptake	SMN 0-30cm	SMN 30-60cm	SMN 60-90cm	Crop N + SMN
Measured values					
0	56	147	44	N/A	247
200	198	118	38	N/A	354
223 (farm) [§]	N/A	72	37	N/A	N/A
WELL_N Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	111	14	7	N/A	153
200	232	14	7	N/A	276
SUNDIAL-FRS Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	76	37	17	N/A	141
200	180	29	54	N/A	273
223 (farm) [§]	163	32	23	N/A	229

* Zero and maximum rates used in trial, plus farm rate[§] where available.

Comments: The soil reaches chalk at 60cm so no SMN measurements were available below this depth. Both models considerably underestimated SMN in the 0-30cm layer. SUNDIAL-FRS showed reasonable agreement between measured and simulated crop N uptake at both N rates. WELL_N overestimated crop N at the zero rate.

APPENDIX B

Site reference: 12

Year: 1999

Topsoil texture:	Clay	Previous crop:	Winter wheat
Current crop:	Winter OSR	Expected mkt yield t/ha:	3.97
Maximum mkt yield t/ha:	5.0	Maximum total DW t/ha:	11.3

Summary of N recommendations (kgN/ha) and calculated yields (t/ha):

Method	Optimum*	RB209	Farm [§]	WELL_N:				SUNDIAL-FRS:			
				Predictive		Retrospective		Predictive		Retrospective	
				Default weather	Actual weather	Default weather	Actual weather	Default weather	+ spring SMN	Actual weather	+ spring SMN
Recommendation	0	190	255	N/A	N/A	N/A	N/A	248	120	248	120
Calculated yield *	4.5	4.5	4.5					4.5	4.5	4.5	4.5
% difference from optimum yield											

* Calculated as mean trial yield, as there was no significant response to N within the range of the trial

§ Farm recommendation is actual rate used by the farmer in the rest of the field.

Comments: There was no significant response to applied N at this site. The SUNDIAL-FRS recommendations were too high, although substantially improved by the use of spring SMN measurements. The RB209 and Farm recommendations were also too high.

WELL_N is not parameterised for oil seed rape.

Crop N uptake and Soil Mineral N (SMN, nitrate plus ammonium) at harvest (kgN/ha)

N rate*	Crop N uptake	SMN 0-30cm	SMN 30-60cm	SMN 60-90cm	Crop N + SMN
Measured values					
0	155	46	33	N/A	234
300	214	304	80	N/A	598
255 (farm) [§]	158	59	38	N/A	255
WELL_N Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	N/A	N/A	N/A	N/A	N/A
300	N/A	N/A	N/A	N/A	N/A
SUNDIAL-FRS Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	145	38	26	N/A	209
300	211	38	217	N/A	466
255 (farm) [§]	212	41	168	N/A	421

* Zero and maximum rates used in trial, plus farm rate[§] where available.

Comments: Soil reaches chalk at 60cm. SUNDIAL-FRS showed good agreement between measured and simulated crop N at both N rates, and was also able to simulate the very high SMN values reasonably under the maximum N rate, although in a deeper soil layer. The good agreement between simulated and measured values, but poor agreement between recommended and optimum N rates suggests that N may be being obtained by other processes. Under some conditions N may be obtained from the porous chalk bedrock, and there is no description of this process in SUNDIAL. Some description of the sequestration of N from porous bedrock could be included in the model.

APPENDIX B

Site reference: 13

Year: 1998

Topsoil texture:	Clay	Previous crop:	Winter wheat
Current crop:	Winter barley	Expected mkt yield t/ha:	7.5
Maximum mkt yield t/ha:	8.5	Maximum total DW t/ha:	11.9

Summary of N recommendations (kgN/ha) and calculated yields (t/ha):

Method	Optimum*	RB209	Farm [§]	WELL_N:				SUNDIAL-FRS:			
				Predictive		Retrospective		Predictive		Retrospective	
				Default weather	Actual weather	Default weather	Actual weather	Default weather	+ spring SMN	Actual weather	+ spring SMN
Recommendation	20 (±16.2)	160	188	125	150	125	125	80	0	80	0
Calculated yield *	6.4	8.3	8.4	8.2	8.3	8.2	8.2	7.9	4.9	7.9	4.9
% difference from optimum yield		30	31	28	30	28	28	23	-23	23	-23

* Calculated from linear plus exponential curve fitted to trial data. Estimated standard error given in brackets.

§ Farm recommendation is actual rate used by the farmer in the rest of the field.

Comments: This was a poor data set, with large errors on the fitted curve parameters, and the calculated optimum should be treated with some caution, although it does lie below 35 kgN/ha. Including the spring SMN values as diagnostics improved the SUNDIAL-FRS recommendation. Using actual weather over the spring in the retrospective simulations had no effect on either WELL_N or SUNDIAL-FRS recommendations. RB209 greatly over-estimated the optimum.

WELL_N is not parameterised for heavy clay soils. Recommended rates and yields were higher than the calculated optimum.

Crop N uptake and Soil Mineral N (SMN, nitrate plus ammonium) at harvest (kgN/ha)

N rate*	Crop N uptake	SMN 0-30cm	SMN 30-60cm	SMN 60-90cm	Crop N + SMN
Measured values					
0	64	30	25	14	133
175	201	39	36	24	300
188 (farm) [§]	N/A	54	25	17	-
WELL_N Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	96	5	5	13	119
175	201	5	5	17	228
SUNDIAL-FRS Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	90	45	20	11	166
175	176	44	76	11	307
188 (farm) [§]					

* Zero and maximum rates used in trial, plus farm rate[§] where available.

Comments: SUNDIAL-FRS overestimated the harvest SMN at the maximum N rate. WELL_N simulated crop N uptake well, but underestimated SMN.

APPENDIX B

Site reference: 13

Year: 1999

Topsoil texture:	Clay	Previous crop:	Winter barley
Current crop:	Winter OSR	Expected mkt yield t/ha:	3.9
Maximum mkt yield t/ha:	3.8	Maximum total DW t/ha:	11.0

Summary of N recommendations (kgN/ha) and calculated yields (t/ha):

Method	Optimum*	RB209	Farm [§]	WELL_N:				SUNDIAL-FRS:			
				Predictive		Retrospective		Predictive		Retrospective	
				Default weather	Actual weather	Default weather	Actual weather	Default weather	+ spring SMN	Actual weather	+ spring SMN
Recommendation	163	190	232	N/A	N/A	N/A	N/A	120	59	120	59
Calculated yield *	3.1	3.2	3.3					2.9	2.3	2.9	2.3
% difference from optimum yield		3	5					-7	-27	-7	-27

* Calculated from linear plus exponential curve fitted to trial data.

§ Farm recommendation is actual rate used by the farmer in the rest of the field.

Comments: WELL_N is not parameterised for OSR.

The SUNDIAL-FRS recommendation was a little low, with the calculated yield 7% less than that achieved by the optimum N rate. Including spring SMN values as diagnostics reduced the recommendation, with a yield reduction of 27%. Using the actual weather in the spring was of no benefit in this simulation.

Crop N uptake and Soil Mineral N (SMN, nitrate plus ammonium) at harvest (kgN/ha)

N rate*	Crop N uptake	SMN 0-30cm	SMN 30-60cm	SMN 60-90cm	Crop N + SMN
Measured values					
0	42	52	31	15	139
300	222	77	42	31	372
232 (farm) [§]	206	62	30	13	311
WELL_N Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	N/A	N/A	N/A	N/A	
300	N/A	N/A	N/A	N/A	
SUNDIAL-FRS Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	30	41	79	28	179
300	183	48	230	13	474
232 (farm) [§]	188	48	221	12	469

* Zero and maximum rates used in trial, plus farm rate[§] where available.

Comments: SUNDIAL-FRS substantially overestimated harvest SMN below 30cm when fertilizer N was applied.

APPENDIX B

Site reference: 14

Year: 1998

Topsoil texture:	Sandy clay loam	Previous crop:	Winter wheat
Current crop:	Winter OSR	Expected mkt yield t/ha:	4.3
Maximum mkt yield t/ha:	7.4	Maximum total DW t/ha:	12.8

Summary of N recommendations (kgN/ha) and calculated yields (t/ha):

Method	Optimum*	RB209	Farm [§]	WELL_N:				SUNDIAL-FRS:			
				Predictive		Retrospective		Predictive		Retrospective	
				Default weather	Actual weather	Default weather	Actual weather	Default weather	+ spring SMN	Actual weather	+ spring SMN
Recommendation	See below	190	238	N/A	N/A	N/A	N/A	158	100	140	100
Calculated yield *	N/A										
% difference from optimum yield											

* Calculated from linear plus exponential curve fitted to trial data.

§ Farm recommendation is actual rate used by the farmer in the rest of the field.

Comments: A response curve could not be fitted to the trial data, as the data was too variable to fit, and no optimum could be derived. Some of the yields derived from the trial were very high for winter OSR, and much higher than the farm rate of 238 kgN/ha used in the remainder of the field (4.3 t/ha).

WELL_N is not parameterised for Winter OSR.

Crop N uptake and Soil Mineral N (SMN, nitrate plus ammonium) at harvest (kgN/ha)

N rate*	Crop N uptake	SMN 0-30cm	SMN 30-60cm	SMN 60-90cm	Crop N + SMN
Measured values					
0	102	44	20	17	183
195	234	86	26	16	362
238 (farm) [§]	N/A	62	16	16	
WELL_N Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	N/A	N/A	N/A	N/A	
195	N/A	N/A	N/A	N/A	
SUNDIAL-FRS Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	137	20	12	9	178
195	365	13	10	9	397
238 (farm) [§]					

* Zero and maximum rates used in trial, plus farm rate[§] where available.

Comments: SUNDIAL-FRS overestimated crop N at both N rates, but underestimated SMN, so that the total crop N + SMN was well simulated.

Site reference: 14**Year: 1999**

Topsoil texture:	Sandy clay loam	Previous crop:	Winter OSR
Current crop:	Winter wheat	Expected mkt yield t/ha:	11.3
Maximum mkt yield t/ha:	9.8	Maximum total DW t/ha:	11.3

Summary of N recommendations (kgN/ha) and calculated yields (t/ha):

Method	Optimum*	RB209	Farm [§]	WELL_N:				SUNDIAL-FRS:			
				Predictive		Retrospective		Predictive		Retrospective	
				Default weather	Actual weather	Default weather	Actual weather	Default weather	+ spring SMN	Actual weather	+ spring SMN
Recommendation	139 (±17.4)	182	124	N/A	N/A	N/A	N/A	162	40	141	40
Calculated yield *	9.1	9.5	8.9					9.3	7.8	9.1	7.8
% difference from optimum yield		4	-2					2	-14	0	-14

* Calculated from linear plus exponential curve fitted to trial data. Estimated standard error given in brackets.

§ Farm recommendation is actual rate used by the farmer in the rest of the field.

Comments: The field received 40t/ha of pig FYM in the autumn. The farm and SUNDIAL-FRS without spring SMN values gave very good recommendations. Including spring SMN values substantially reduced the recommendations, and reduced the calculated yield well below the optimum. The reduction in the recommendation may be due to inaccurate parameters describing the quality of the pig FYM. If the simulation of N mineralisation from the applied FYM does not have the correct time profile, a simple addition of measured SMN would introduce an error. Farmyard manures are inherently variable in nature. The farmyard manure parameters are based on an average pig FYM type. There is a need to develop a manure module that will allow improved description of a specific manure according to diagnostic manure measurements and information that is available to farmers.

WELL_N does not have routines for dealing with organic manures.

Crop N uptake and Soil Mineral N (SMN, nitrate plus ammonium) at harvest (kgN/ha)

N rate*	Crop N uptake	SMN 0-30cm	SMN 30-60cm	SMN 60-90cm	Crop N + SMN
Measured values					
0	132	28	21	19	200
250	201	35	42	26	304
124 (farm) [§]	185	16	39	17	257
WELL_N Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	N/A	N/A	N/A	N/A	
250	N/A	N/A	N/A	N/A	
SUNDIAL-FRS Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	161	28	51	9	249
250	237	28	64	9	338
124 (farm) [§]	244	28	97	11	380

* Zero and maximum rates used in trial, plus farm rate[§] where available.

Comments: Note the very similar measured crop N uptake from the farm and maximum N rate field plots. The farm plots received half the N rate of the maximum trial plot, but gave the same yield (10 t/ha). The farm N was applied much later than the trial N (mid April and mid May, compared to early March and early April), demonstrating the importance of timing of N applications as well as the amount of N applied. SUNDIAL-FRS slightly overestimated crop N uptake at all N rates, and gave a high SMN simulation under the farm rate.

APPENDIX B

Site reference: 15

Year: 1998

Topsoil texture:	Sandy clay loam	Previous crop:	Vining peas
Current crop:	Winter wheat	Expected mkt yield t/ha:	10.0
Maximum mkt yield t/ha:	11.7	Maximum total DW t/ha:	20.5

Summary of N recommendations (kgN/ha) and calculated yields (t/ha):

Method	Optimum*	RB209	Farm [§]	WELL_N:				SUNDIAL-FRS:			
				Predictive		Retrospective		Predictive		Retrospective	
				Default weather	Actual weather	Default weather	Actual weather	Default weather	+ spring SMN	Actual weather	+ spring SMN
Recommendation	0	190	84	N/A	N/A	N/A	N/A	140	0	140	0
Calculated yield *	10.4	10.4	10.4					10.4	10.4	10.4	10.4
% difference from optimum yield											

* Calculated as mean trial yield, as there was no significant response to N within the range of the trial.

§ Farm recommendation is actual rate used by the farmer in the rest of the field.

Comments: 45 t/ha of pig FYM was applied in the autumn of 1997, which precluded the use of WELL_N. There was no significant response to N applied in the trial. The initial SUNDIAL-FRS recommendation was too high; but once the spring SMN measurement was included, the recommendation was correctly reduced to 0 kg N/ha. Using real weather data from the date of fertiliser application had no effect on the recommendation. The recommendation given by RB209 was too high.

Crop N uptake and Soil Mineral N (SMN, nitrate plus ammonium) at harvest (kgN/ha)

N rate*	Crop N uptake	SMN 0-30cm	SMN 30-60cm	SMN 60-90cm	Crop N + SMN
Measured values					
0	267	87	53	36	443
180	305	122	60	50	537
84 (farm) [§]	N/A	86	64	54	
WELL_N Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	N/A	N/A	N/A	N/A	
180	N/A	N/A	N/A	N/A	
SUNDIAL-FRS Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	243	27	28	9	307
180	256	32	147	9	438
84 (farm) [§]	304	28	47	9	388

* Zero and maximum rates used in trial, plus farm rate[§] where available.

Comments: SUNDIAL-FRS simulated crop N very well in the zero N plot. It was unable to simulate the luxury uptake of N by the crop in the plots given fertiliser N, which had very similar yields to the unfertilised plot, so tended to simulate too much mineral N in the soil. Including the variable N uptake module into SUNDIAL-FRS would improve this simulation. SUNDIAL underestimated SMN at both N rates.

APPENDIX B

Site reference: 15

Year: 1999

Topsoil texture:	Sandy clay loam	Previous crop:	Winter wheat
Current crop:	Sugar beet	Expected mkt yield t/ha:	95
Maximum mkt yield t/ha:	88	Maximum total DW t/ha:	25.0

Summary of N recommendations (kgN/ha) and calculated yields (t/ha):

Method	Optimum*	RB209	Farm [§]	WELL_N:				SUNDIAL-FRS:			
				Predictive		Retrospective		Predictive		Retrospective	
				Default weather	Actual weather	Default weather	Actual weather	Default weather	+ spring SMN	Actual weather	+ spring SMN
Recommendation	0	21	192	N/A	N/A	N/A	N/A	0	0	0	0
Calculated yield *	68.9	68.9	68.9					68.9	68.9	68.9	68.9
% difference from optimum yield											

* Calculated as mean trial yield, as there was no significant response to N within the range of the trial.

§ Farm recommendation is actual rate used by the farmer in the rest of the field.

Comments: There was no significant response to applied N. 35 t/ha of duck FYM was applied to the trial in autumn 1998; duck FYM is not parameterised in SUNDIAL-FRS so layer manure was used instead. SUNDIAL-FRS correctly recommended that no fertiliser N should be applied, with and without the spring SMN measurements. WELL_N does not include routines for handling organic manures. The farmer over-estimated the amount of fertiliser N needed.

Crop N uptake and Soil Mineral N (SMN, nitrate plus ammonium) at harvest (kgN/ha)

N rate*	Crop N uptake	SMN 0-30cm	SMN 30-60cm	SMN 60-90cm	Crop N + SMN
Measured values					
0	209	29	15	12	265
150	234	32	19	14	299
192 (farm) [§]	N/A	N/A	N/A	N/A	N/A
WELL_N Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	N/A	N/A	N/A	N/A	
150	N/A	N/A	N/A	N/A	
SUNDIAL-FRS Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	218	10	20	18	266
150	224	10	20	18	272
192 (farm) [§]					

* Zero and maximum rates used in trial, plus farm rate[§] where available.

Comments: SUNDIAL-FRS correctly simulated the crop N and SMN at harvest at both fertiliser rates.

APPENDIX B

Site reference: 16

Year: 1998

Topsoil texture:	Silt loam	Previous crop:	Set-aside
Current crop:	Winter wheat	Expected mkt yield t/ha:	12.0
Maximum mkt yield t/ha:	10.7	Maximum total DW t/ha:	16.2

Summary of N recommendations (kgN/ha) and calculated yields (t/ha):

Method	Optimum*	RB209	Farm [§]	WELL_N:				SUNDIAL-FRS:			
				Predictive		Retrospective		Predictive		Retrospective	
				Default weather	Actual weather	Default weather	Actual weather	Default weather	+ spring SMN	Actual weather	+ spring SMN
Recommendation	94 (±2.6)	260	130	125	150	75	125	340	240	280	180
Calculated yield *	10.2	11.3	10.5	10.5	10.6	10.0	10.5	N/A	N/A	N/A	10.8
% difference from optimum yield		11	3	3	4	-2	3				6

* Calculated from linear plus exponential curve fitted to trial data. Estimated standard error given in brackets.

§ Farm recommendation is actual rate used by the farmer in the rest of the field.

Comments: SUNDIAL-FRS gave far too high a predictive recommendation. Using spring SMN values reduced the recommendation by 100 kgN/ha, but it was still too high. Yields were not calculated for the SUNDIAL predictive recommendations as they were well above the maximum trial N rate of 155 kg N/ha. The SUNDIAL-FRS retrospective recommendations used a yield of 10.2 t/ha. This reduced the recommendation to 180 kg N/ha (with actual weather and spring SMN measurements), still 86 kg N/ha more than the optimum, but within 6% of the calculated yield at the optimum rate. The RB209 recommendation was also too high.

WELL_N gave a good recommendation, being within 50 kg N/ha of the optimum and 5% of the yield. Using actual weather the WELL_N recommendations were increased by 25-50 kg N/ha.

Crop N uptake and Soil Mineral N (SMN, nitrate plus ammonium) at harvest (kgN/ha)

N rate*	Crop N uptake	SMN 0-30cm	SMN 30-60cm	SMN 60-90cm	Crop N + SMN
Measured values					
0	97	17	11	8	133
155	191	21	10	8	230
130 (farm) [§]	N/A	27	9	9	
WELL_N Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	129	15	7	6	157
155	220	15	7	6	248
SUNDIAL-FRS Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	91	17	15	9	132
155	240	14	12	9	275
130 (farm) [§]	220	14	10	9	253

* Zero and maximum rates used in trial, plus farm rate[§] where available.

Comments: SUNDIAL-FRS and WELL_N simulated SMN at harvest well, but tended to overestimate crop N at the maximum N rates.

APPENDIX B

Site reference: 16 Year: 1999

Topsoil texture: **Silt loam** Previous crop: **Winter wheat**
 Current crop: **Dutch white cabbage** Expected mkt yield t/ha: **48.8**
 Maximum mkt yield t/ha: **47.4** Maximum total DW t/ha: **9.0**

Summary of N recommendations (kgN/ha) and calculated yields (t/ha):

Method	Optimum*	RB209	Farm [§]	WELL_N:				SUNDIAL-FRS:			
				Predictive		Retrospective		Predictive		Retrospective	
				Default weather	Actual weather	Default weather	Actual weather	Default weather	+ spring SMN	Actual weather	+ spring SMN
Recommendation	253 (±14.5)	250	200	225	225	275	275	300	0	300	300
Calculated yield *	45.5	45.3	42.1	43.9	43.9	46.4	46.4	47.2	18.8	47.2	47.2
% difference from optimum yield		0	-7	-3	-3	2	2	4	-58	4	4

* Calculated from linear plus exponential curve fitted to trial data. Estimated standard error given in brackets.

§ Farm recommendation is actual rate used.

Comments: Farm rate limited to 200 kgN/ha by supermarket requirements. Good assessment of marketable yield based on stand and average marketable head weight. WELL_N recommendations were within 50 kgN/ha of optimum and unaffected by actual weather. Predictive recommendation 50 kgN/ha lower than retrospective since conversion of marketable fresh weight to dry weight 30% lower than expected from WELL_N defaults. SUNDIAL-FRS recommendations were also within 50 kgN/ha of optimum, except predictive with SMN, which gave a very unexpected result. This was due to poor simulation of crop N uptake.

Crop N uptake and Soil Mineral N (SMN, nitrate plus ammonium) at harvest (kgN/ha)

N rate*	Crop N uptake	Soil 0-30cm	Soil 30-60cm	Soil 60-90cm	Crop N + SMN
Measured values					
0	51	19	9	6	85
350	184	34	11	8	237
200 (farm) [§]					
WELL_N Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	81	22	16	18	137
350	305	15	14	14	348
SUNDIAL-FRS Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	4	20	50	22	95
350	15	26	346	22	409
200 (farm) [§]					

Zero and maximum rates used in trial, plus farm rate[§] where available.

Comments: SUNDIAL-FRS was unable to simulate N uptake by the crop, hence all the fertilizer N accumulated in the soil. WELL_N overestimated crop N uptake at the maximum N rate.

APPENDIX B

Site reference: 17

Year: 1998

Topsoil texture:	Clay	Previous crop:	Winter beans
Current crop:	Winter wheat	Expected mkt yield t/ha:	9.0
Maximum mkt yield t/ha:	8.2	Maximum total DW t/ha:	14

Summary of N recommendations (kgN/ha) and calculated yields (t/ha):

Method	Optimum*	RB209	Farm [§]	WELL_N:				SUNDIAL-FRS:			
				Predictive		Retrospective		Predictive		Retrospective	
				Default weather	Actual weather	Default weather	Actual weather	Default weather	+ spring SMN	Actual weather	+ spring SMN
Recommendation	61	150	160	25	75	25	75	20	0	40	0
Calculated yield *	7.3	6.3	5.7	6.9	7.4	6.9	7.4	6.9	6.6	7.1	6.6
% difference from optimum yield		-14	-23	-5	1	-5	1	-6	-9	-3	-9

* Calculated from linear plus exponential curve fitted to trial data.

§ Farm recommendation is actual rate used by the farmer in the rest of the field.

Comments: There was a decline in yield with N applications above 100 kgN/ha. Both RB209 and farm practice overestimated N requirement, leading to large reductions in yield. SUNDIAL-FRS recommendations were slightly low, and were not greatly affected by actual weather or spring SMN measurements. All model recommendations produced calculated yields within 10% of the optimum. WELL_N is not parameterised for heavy clay soils and gave slightly low recommendations with default weather. These were improved by using actual weather achieving yields within 1% of the optimum.

Crop N uptake and Soil Mineral N (SMN, nitrate plus ammonium) at harvest (kgN/ha)

N rate*	Crop N uptake	SMN 0-30cm	SMN 30-60cm	SMN 60-90cm	Crop N + SMN
Measured values					
0	152	57	28	10	247
150	209	32	17	9	267
160 (farm) [§]	N/A	21	13	14	
WELL_N Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	146	12	6	6	170
150	235	12	6	6	259
SUNDIAL-FRS Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	142	38	36	34	250
150	137	39	176	48	400
160 (farm) [§]	196	38	153	23	410

* Zero and maximum rates used in trial, plus farm rate[§] where available.

Comments: SUNDIAL-FRS considerably underestimated crop N uptake at the maximum N rate, and hence accumulated fertilizer N as SMN in the soil. Yields at the zero and maximum rates were almost the same, 6.6 and 6.4 t/ha respectively. SUNDIAL-FRS was unable to simulate the luxury uptake by the wheat when given fertiliser N. Including the variable N uptake module in SUNDIAL-FRS would improve these simulations. WELL_N simulated crop N well at both N rates, but underestimated SMN.

APPENDIX B

Site reference: 17

Year: 1999

Topsoil texture:	Clay	Previous crop:	Winter wheat
Current crop:	Winter wheat	Expected mkt yield t/ha:	8.5
Maximum mkt yield t/ha:	7.7	Maximum total DW t/ha:	10.7

Summary of N recommendations (kgN/ha) and calculated yields (t/ha):

Method	Optimum*	RB209	Farm [§]	WELL_N:				SUNDIAL-FRS:			
				Predictive		Retrospective		Predictive		Retrospective	
				Default weather	Actual weather	Default weather	Actual weather	Default weather	+ spring SMN	Actual weather	+ spring SMN
Recommendation	228 (±19.3)	190	220	150	125	125	125	120	20	120	20
Calculated yield *	7.5	7.1	7.4	6.5	6.1	6.1	6.1	6.0	3.5	6.0	3.5
% difference from optimum yield		-5	-1	-12	-18	-18	-18	-19	-53	-19	-53

* Calculated from linear plus exponential curve fitted to trial data. Estimated standard error given in brackets.

§ Farm recommendation is actual rate used by the farmer in the rest of the field.

Comments: SUNDIAL-FRS gave a poor recommendation, well below the optimum. Including spring SMN measurements resulted in a worse recommendation. WELL_N is not parameterised for heavy clay soils and underestimated the optimum. The farm rate of 220 kgN/ha used in the remainder of the field gave a higher yield (8.3 t/ha) than the trial maximum (7.7 t/ha), suggesting that timing of N applications was important.

Crop N uptake and Soil Mineral N (SMN, nitrate plus ammonium) at harvest (kgN/ha)

N rate*	Crop N uptake	SMN 0-30cm	SMN 30-60cm	SMN 60-90cm	Crop N + SMN
Measured values					
0	42	122	35	46	245
250	136	212	55	46	449
220(farm) [§]	154	76	37	27	294
WELL_N Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	141	13	6	6	166
250	205	53	63	46	367
SUNDIAL-FRS Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	58	34	90	38	220
250	164	34	197	38	433
220 (farm) [§]	209	34	165	11	419

* Zero and maximum rates used in trial, plus farm rate[§] where available.

Comments: SUNDIAL-FRS simulated crop N uptake reasonably well, and also simulated the high SMN values, although not always in the correct soil layer. WELL_N overestimated crop N uptake at both rates and tended to underestimate SMN, particularly in the 0-30 cm layer. Note the very high SMN values at harvest, even in the unfertilised plot. Spring SMN was not especially high (141 kgN/ha 0-90cm), and no manure was applied. Inadvertent N application to the trial is unlikely, as N uptake at the zero N rate is low, and the response curve is one of the steepest. Measurements of gross mineralisation at this site (MAFF project NT 1520) showed the highest rates measured for 1999 due to over-compaction following drilling. In autumn these were balanced by high rates of immobilisation, however, this may not have occurred throughout the growing season.

APPENDIX B

Site reference: 18

Year: 1998

Topsoil texture:	Silty clay loam	Previous crop:	Celery
Current crop:	Winter wheat	Expected mkt yield t/ha:	10
Maximum mkt yield t/ha:	8.6	Maximum total DW t/ha:	14.5

Summary of N recommendations (kgN/ha) and calculated yields (t/ha):

Method	Optimum*	RB209	Farm [§]	WELL_N:				SUNDIAL-FRS:			
				Predictive		Retrospective		Predictive		Retrospective	
				Default weather	Actual weather	Default weather	Actual weather	Default weather	+ spring SMN	Actual weather	+ spring SMN
Recommendation	See below	220	N/A	150	150	125	150	N/A	N/A	N/A	N/A
Calculated yield *	N/A										
% difference from optimum yield											

* Calculated from linear plus exponential curve fitted to trial data.

§ Farm recommendation is actual rate used by the farmer in the rest of the field.

Comments: A response curve could not be fitted to the trial data, as it was too variable.

The three previous crops were celery, for which SUNDIAL-FRS is not parameterised.

Crop N uptake and Soil Mineral N (SMN, nitrate plus ammonium) at harvest (kgN/ha)

N rate*	Crop N uptake	SMN 0-30cm	SMN 30-60cm	SMN 60-90cm	Crop N + SMN
Measured values					
0	53	22	14	12	101
145	151	30	17	13	211
(farm) [§]	N/A	21	13	10	
WELL_N Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	95	14	6	6	121
145	183	14	6	6	209
SUNDIAL-FRS Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	N/A	N/A	N/A	N/A	
145	N/A	N/A	N/A	N/A	
(farm) [§]					

* Zero and maximum rates used in trial, plus farm rate[§] where available.

Comments: WELL_N overestimated crop uptake but simulated soil N reasonably well.

APPENDIX B

Site reference: 19

Year: 1998

Topsoil texture:	Sandy loam	Previous crop:	Winter OSR
Current crop:	Winter wheat	Expected mkt yield t/ha:	10.4
Maximum mkt yield t/ha:	10.2	Maximum total DW t/ha:	15

Summary of N recommendations (kgN/ha) and calculated yields (t/ha):

Method	Optimum*	RB209	Farm [§]	WELL_N:				SUNDIAL-FRS:			
				Predictive		Retrospective		Predictive		Retrospective	
				Default weather	Actual weather	Default weather	Actual weather	Default weather	+ spring SMN	Actual weather	+ spring SMN
Recommendation	See below	190	212	100	150	75	150	260	180	260	180
Calculated yield *	N/A	10.3	10.5	9.3	9.9	9.0	9.9	11.0	10.2	11.0	10.2
% difference from optimum yield											

* Calculated from linear plus exponential curve fitted to trial data.

§ Farm recommendation is actual rate used by the farmer in the rest of the field.

Comments: The optimum was above the maximum N rate used in the trial (170kgN/ha), but was probably around 180 kgN/ha as the farm rate achieved a yield of 10.4 t/ha on the remainder of the field, compared to 10.2 from the trial maximum. This suggests that the SUNDIAL recommendations with SMN were about right. WELL_N tended to recommend low, but was noticeably affected by actual weather at this site.

Crop N uptake and Soil Mineral N (SMN, nitrate plus ammonium) at harvest (kgN/ha)

N rate*	Crop N uptake	SMN 0-30cm	SMN 30-60cm	SMN 60-90cm	Crop N + SMN
Measured values					
0	73	25	11	11	120
170	240	40	15	11	306
210 [§]	N/A	29	14	12	
WELL_N Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	182	14	26	46	268
170	252	14	52	62	380
SUNDIAL-FRS Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	100	20	26	9	155
170	250	15	14	9	288
210 [§]	258	30	30	9	327

* Zero and maximum rates used in trial, plus farm rate[§] where available.

Comments: Both WELL_N and SUNDIAL overestimated crop N uptake at zero. WELL_N also overestimated SMN at the 30-90 cm depth. SUNDIAL gave good simulation at the maximum N rate.

APPENDIX B

Site reference: 19

Year: 1999

Topsoil texture: **Sandy loam**
 Current crop: **Potatoes**
 Maximum mkt yield t/ha: **53**

Previous crop: **Winter wheat**
 Expected mkt yield t/ha: **45**
 Maximum total DW t/ha: **11.6**

Summary of N recommendations (kgN/ha) and calculated yields (t/ha):

Method	Optimum*	RB209	Farm [§]	WELL_N:				SUNDIAL-FRS:			
				Predictive		Retrospective		Predictive		Retrospective	
				Default weather	Actual weather	Default weather	Actual weather	Default weather	+ spring SMN	Actual weather	+ spring SMN
Recommendation	0 (See below)	240	212	0	0	0	0	0	N/A	0	N/A
Calculated yield *	48.5	48.5	48.5	48.5	48.5	48.5	48.5	48.5	N/A	48.5	N/A
% difference from optimum yield											

* Calculated as mean trial yield, as there was no significant response to N within the range of the trial.

[§] Farm recommendation is actual rate used by the farmer in the rest of the field.

Comments: A basal N rate of 212 kgN/ha was inadvertently applied uniformly to the site before N rates were imposed. There was no response to additional N applied. The SUNDIAL-FRS and WELL_N recommendations made after the application of the basal N correctly recommended that no additional N should be applied. The spring SMN measurements were taken after the basal application so could not be used as a diagnostic for SUNDIAL-FRS.

Crop N uptake and Soil Mineral N (SMN, nitrate plus ammonium) at harvest (kgN/ha)

N rate*	Crop N uptake	SMN 0-30cm	SMN 30-60cm	SMN 60-90cm	Crop N + SMN
Measured values					
0 (212)	196	51	36	48	331
362	213	110	129	72	524
212 (farm) [§]	N/A	N/A	N/A	N/A	
WELL_N Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0 (212)	212	14	26	46	298
362	252	14	52	62	380
SUNDIAL-FRS Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0 (212)	240	12	34	49	335
362	261	11	149	57	478
212 (farm) [§]					

* Zero and maximum rates used in trial, plus farm rate[§] where available.

Comments: There was very good agreement between SUNDIAL-FRS and measured crop N and SMN at harvest. WELL_N underestimated SMN in the 0-60 cm layer.

APPENDIX B

Site reference: 20

Year: 1999

Topsoil texture:	Sandy clay loam	Previous crop:	Sugar beet
Current crop:	Winter wheat	Expected mkt yield t/ha:	8
Maximum mkt yield t/ha:	8.1	Maximum total DW t/ha:	11.1

Summary of N recommendations (kgN/ha) and calculated yields (t/ha):

Method	Optimum*	RB209	Farm [§]	WELL_N:				SUNDIAL-FRS:			
				Predictive		Retrospective		Predictive		Retrospective	
				Default weather	Actual weather	Default weather	Actual weather	Default weather	+ spring SMN	Actual weather	+ spring SMN
Recommendation	168 (±15.4)	210	166	125	125	100	100	237	180	237	180
Calculated yield *	8.0	8.1	8.0	7.4	7.4	7.0	7.0	8.1	8.1	8.1	8.1
% difference from optimum yield		2	0	-16	-16	-12	-12	1	1	1	1

* Calculated from linear plus exponential curve fitted to trial data. Estimated standard error given in brackets.

§ Farm recommendation is actual rate used by the farmer in the rest of the field.

Comments: The SUNDIAL-FRS recommendation is improved with the use of spring SMN as a diagnostic measurement. The SUNDIAL, RB209 and farm recommendations were all within 2% of the optimum yield. The SUNDIAL recommendations with SMN were within the standard error of the optimum. WELL_N underestimated the optimum requirement, resulting in a yield loss of 12-16%.

Crop N uptake and Soil Mineral N (SMN, nitrate plus ammonium) at harvest (kgN/ha)

N rate*	Crop N uptake	SMN 0-30cm	SMN 30-60cm	SMN 60-90cm	Crop N + SMN
Measured values					
0	56	29	22	15	122
250	132	61	36	12	241
166 (farm) [§]	113	32	23	15	183
WELL_N Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	121	15	7	6	149
250	210	31	65	27	333
SUNDIAL-FRS Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	46	12	9	9	76
250	182	25	79	9	295
166 (farm) [§]	145	17	27	9	198

* Zero and maximum rates used in trial, plus farm rate[§] where available.

Comments: There was good agreement between SUNDIAL-FRS and measured crop N harvest in the zero N rate. SUNDIAL-FRS and WELL_N overestimated N in the crop at the maximum N rate.

APPENDIX B

Site reference: 21

Year: 1999(1)

Topsoil texture: **Sandy clay loam**

Previous crop: **Winter barley**

Current crop: **Spinach**

Expected mkt yield t/ha: **23.0**

Maximum mkt yield t/ha: **23.0**

Maximum total DW t/ha: **2.3**

Summary of N recommendations (kgN/ha) and calculated yields (t/ha):

Method	Optimum*	RB209	Farm [§]	WELL_N:				SUNDIAL-FRS:			
				Predictive		Retrospective		Predictive		Retrospective	
				Default weather	Actual weather	Default weather	Actual weather	Default weather	+ spring SMN	Actual weather	+ spring SMN
Recommendation	201 (±6.1)	N/A	100	125	125	125	125	N/A	N/A	N/A	N/A
Calculated yield *	25.5		18.8	20.9	20.9	20.9	20.9				
% difference from optimum yield			-26	-18	-18	-18	-18				

* Calculated from linear plus exponential curve fitted to trial data. Estimated standard error given in brackets.

§ Farm recommendation is actual rate used.

Comments: No RB209 recommendation for this crop. A planned top-dressing by the farmer was omitted because of wet soil conditions. Spinach is a fast growing crop, making it difficult to estimate the optimum from a single harvest. Trial application of 200 kgN/ha, close to the calculated optimum, judged overmature by farmer on day of harvest - rate of 150 kgN/ha judged to be optimum quality. NO₃N in fresh weight marketable exceeded E.C. limit of 2500 ppm for N application rates greater than 150 kgN/ha. WELL_N gave good prediction and retrospective estimation of the N rate for optimum quality. The farm crop was in oversupply and was ploughed in.

SUNDIAL-FRS is not parameterised for spinach.

Crop N uptake and Soil Mineral N (SMN, nitrate plus ammonium) at harvest (kgN/ha)

N rate*	Crop N uptake	Soil 0-30cm	Soil 30-60cm	Soil 60-90cm	Crop N + SMN
Measured values					
0	37	28	30	23	118
250	129	152	59	27	367
(farm) [§]	N/A	N/A	N/A	N/A	
WELL_N Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	18	45	55	51	169
250	81	201	55	51	388
SUNDIAL-FRS Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	N/A	N/A	N/A	N/A	
250	N/A	N/A	N/A	N/A	

Zero and maximum rates used in trial, plus farm rate[§] where available.

Comments: WELL_N underestimated crop N uptake and tended to overestimated SMN

APPENDIX B

Site reference: 21

Year: 1999(2)

Topsoil texture: **Sandy clay loam**

Previous crop: **Spinach**

Current crop: **Spinach**

Expected mkt yield t/ha: **23.0**

Maximum mkt yield t/ha: **24.7**

Maximum total DW t/ha: **2.1**

Summary of N recommendations (kgN/ha) and calculated yields (t/ha):

Method	Optimum*	RB209	Farm [§]	WELL_N:				SUNDIAL-FRS:			
				Predictive		Retrospective		Predictive		Retrospective	
				Default weather	Actual weather	Default weather	Actual weather	Default weather	+ spring SMN	Actual weather	+ spring SMN
Recommendation	42 (±9)	N/A	172	50	75	50	75	N/A	N/A	N/A	N/A
Calculated yield *	25.3		24.4	25.4	25.6	25.4	25.6				
% difference from optimum yield			-3	1	1	1	1				

* Calculated from linear plus exponential curve fitted to trial data. Estimated standard error given in brackets.

§ Farm recommendation is actual rate used.

Comments: No RB209 recommendation for this crop. High residue situation, with previous crop entirely ploughed in, giving a low optimum requirement. Farmer did not allow for N in the crop residues, and overestimated requirement. In contrast to the first crop at this site, NO₃N in fresh weight marketable did not exceed the E.C. limit of 2500 ppm at any of the N application rates. WELL_N predictive and retrospective recommendations were within 50 kgN/ha of the calculated optimum.

SUNDIAL-FRS is not parameterised for spinach.

Crop N uptake and Soil Mineral N (SMN, nitrate plus ammonium) at harvest (kgN/ha)

N rate*	Crop N uptake	Soil 0-30cm	Soil 30-60cm	Soil 60-90cm	Crop N + SMN
Measured values					
0	97	54	70	55	276
250	112	182	204	81	579
(farm) [§]	N/A	N/A	N/A	N/A	
WELL_N Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	69	28	63	57	217
250	88	216	97	60	461
SUNDIAL-FRS Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	N/A	N/A	N/A	N/A	
250	N/A	N/A	N/A	N/A	

Zero and maximum rates used in trial, plus farm rate[§] where available.

Comments: WELL_N tended to underestimate crop N uptake and poorly estimated the distribution of SMN, particularly at the maximum application rate.

APPENDIX B

Site reference: 22

Year: 1998

Topsoil texture:	Sandy loam	Previous crop:	Winter wheat
Current crop:	Red bulb onion	Expected mkt yield t/ha:	45.0
Maximum mkt yield t/ha:	30.0	Maximum total DW t/ha:	6.1

Summary of N recommendations (kgN/ha) and calculated yields (t/ha):

Method	Optimum*	RB209	Farm [§]	WELL_N:				SUNDIAL-FRS:			
				Predictive		Retrospective		Predictive		Retrospective	
				Default weather	Actual weather	Default weather	Actual weather	Default weather	+ spring SMN	Actual weather	+ spring SMN
Recommendation	0	90	215	100	175	100	175	140	40	140	40
Calculated yield *											
% difference from optimum yield											

* Calculated from linear plus exponential curve fitted to trial data.

§ Farm recommendation is actual rate used.

Comments: The farm crop and trial were severely damaged by a storm on 9 April. To aid recovery of the farm crop, 3 top-dressings were applied by contractors during the season. From the lack of response to N on the trial and the high post-harvest SMN on the zero plots, it was assumed that at least one of the top-dressings had been accidentally applied to the trial. The results were therefore not used for model evaluations.

With heavy rain falling shortly after fertiliser application on the trial, the WELL_N predictions with actual weather were 75 kgN/ha higher than with the default weather. Actual weather had no effect on the SUNDIAL-FRS recommendation. The use of SMN reduced the recommendations by 100 kgN/ha.

Crop N uptake and Soil Mineral N (SMN, nitrate plus ammonium) at harvest (kgN/ha)

N rate*	Crop N uptake	Soil 0-30cm	Soil 30-60cm	Soil 60-90cm	Crop N + SMN
Measured values					
0	103	140	52	59	354
215	121	132	61	91	405
215 (farm) [§]	N/A	N/A	N/A	N/A	
WELL_N Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0					
215					
SUNDIAL-FRS Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0					
215					

Zero and maximum rates used in trial, plus farm rate[§] where available.

Comments: Due to the accidental application of N to the trial, crop and SMN simulations are not presented.

APPENDIX B

Site reference: 22

Year: 1999

Topsoil texture: **Sandy loam**

Previous crop: **Red bulb onion**

Current crop: **Parsnip**

Expected mkt yield t/ha: **40.0**

Maximum mkt yield t/ha: **32.0**

Maximum total DW t/ha: **8.6**

Summary of N recommendations (kgN/ha) and calculated yields (t/ha):

Method	Optimum*	RB209	Farm §	WELL_N:				SUNDIAL-FRS:			
				Predictive		Retrospective		Predictive		Retrospective	
				Default weather	Actual weather	Default weather	Actual weather	Default weather	+ spring SMN	Actual weather	+ spring SMN
Recommendation	167	100	110	50	75	75	75	N/A	N/A	N/A	N/A
Calculated yield *	31.4	28.9	29.3	26.8	27.8	27.8	27.8				
% difference from optimum yield		-8	-7	-14	-11	-11	-11				

* Calculated from linear plus exponential curve fitted to trial data.

§ Farm recommendation is actual rate used.

Comments: The crop responded to levels of N considerably in excess of both the RB209 recommendation and farm practice. This was possibly because of poor weed control on the trial plots and commercial area for much of the season. WELL_N also underestimated N requirement, possibly for the same reason, but it also proved difficult to estimate the date of maximum potential dry matter of this overwintered crop where foliage had died back before harvest.

SUNDIAL-FRS is not parameterised for parsnip.

Crop N uptake and Soil Mineral N (SMN, nitrate plus ammonium) at harvest (kgN/ha)

N rate*	Crop N uptake	Soil 0-30cm	Soil 30-60cm	Soil 60-90cm	Crop N + SMN
Measured values					
0	75	12	6	5	98
200	111	12	14	40	177
(farm)§	N/A	N/A	N/A	N/A	
WELL_N Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	108	30	16	15	169
200	198	30	16	15	259
SUNDIAL-FRS Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	N/A	N/A	N/A	N/A	
200	N/A	N/A	N/A	N/A	

Zero and maximum rates used in trial, plus farm rate§ where available.

Comments: WELL_N tended to overestimate crop N and SMN.

APPENDIX B

Site reference: 23

Year: 1998

Topsoil texture: **Silt loam** Previous crop: **Winter wheat**
 Current crop: **Bulb onion (sets)** Expected mkt yield t/ha: **50.0**
 Maximum mkt yield t/ha: **55.0** Maximum total DW t/ha: **10.6**

Summary of N recommendations (kgN/ha) and calculated yields (t/ha):

Method	Optimum*	RB209	Farm [§]	WELL_N:				SUNDIAL-FRS:			
				Predictive		Retrospective		Predictive		Retrospective	
				Default weather	Actual weather	Default weather	Actual weather	Default weather	+ spring SMN	Actual weather	+ spring SMN
Recommendation	137 (±6.5)	90	140	150	175	175	200	180	180	180	180
Calculated yield *	54.2	50.7	54.4	54.9	55.4	55.4	54.9	55.4	55.4	55.4	55.4
% difference from optimum yield		-7	0	1	2	2	1	2	2	2	2

* Calculated from linear plus exponential curve fitted to trial data. Estimated standard error given in brackets.

§ Farm recommendation is actual rate used.

Comments: The calculated optimum was very close to farm practice but RB209 underestimated N requirement. WELL_N predictions were good but increased by 25 kgN/ha for both actual weather and the higher than expected dry matter yield. SUNDIAL-FRS recommendations were too high, but the calculated yield was within 2% of the optimum.

Crop N uptake and Soil Mineral N (SMN, nitrate plus ammonium) at harvest (kgN/ha)

N rate*	Crop N uptake	Soil 0-30cm	Soil 30-60cm	Soil 60-90cm	Crop N + SMN
Measured values					
0	81	36	23	27	167
225	163	69	37	33	302
(farm) [§]	N/A	N/A	N/A	N/A	
WELL_N Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	46	14	18	16	94
225	165	19	35	20	239
SUNDIAL-FRS Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	63	9	9	9	90
225	202	11	51	25	290

Zero and maximum rates used in trial, plus farm rate[§] where available.

Comments: Both WELL_N and SUNDIAL-FRS underestimated crop N uptake at zero, and underestimated SMN in the 0-30 cm layer at both rates. The high measured SMN near the surface could result from the breakdown of the onion tops, which had largely died back by harvest. The models do not take this into account.

APPENDIX B

Site reference: 24

Year: 1998

Topsoil texture: **Silt loam** Previous crop: **Summer cabbage**
 Current crop: **Calabrese** Expected mkt yield t/ha: **11.1**
 Maximum mkt yield t/ha: **14.2** Maximum total DW t/ha: **4.5**

Summary of N recommendations (kgN/ha) and calculated yields (t/ha):

Method	Optimum*	RB209	Farm §	WELL_N:				SUNDIAL-FRS:			
				Predictive		Retrospective		Predictive		Retrospective	
				Default weather	Actual weather	Default weather	Actual weather	Default weather	+ spring SMN	Actual weather	+ spring SMN
Recommendation	250	190	275	100	100	200	200	N/A	N/A	N/A	N/A
Calculated yield *	14.5	12.6	14.2	8.8	8.8	13.0	13.0				
% difference from optimum yield		-13	-2	-40	-40	-11	-11				

* Calculated from linear plus exponential curve fitted to trial data.

§ Farm recommendation is actual rate used.

Comments: RB209 and WELL_N used predictively both underestimated N requirement. The latter was due to a nearly 30% underestimate of the potential marketable yield.

SUNDIAL-FRS is not parameterised for calabrese.

Crop N uptake and Soil Mineral N (SMN, nitrate plus ammonium) at harvest (kgN/ha)

N rate*	Crop N uptake	Soil 0-30cm	Soil 30-60cm	Soil 60-90cm	Crop N + SMN
Measured values					
0	61	64	33	41	199
275	147	39	39	55	280
(farm)§	N/A	N/A	N/A	N/A	
WELL_N Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	40	51	31	52	174
275	198	72	33	52	355
SUNDIAL-FRS Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	N/A	N/A	N/A	N/A	
275	N/A	N/A	N/A	N/A	

Zero and maximum rates used in trial, plus farm rate[§] where available.

Comments: WELL_N underestimated crop N uptake at zero, but overestimated at the high rate.

APPENDIX B

Site reference: 25

Year: 1998

Topsoil texture: **Loamy sand**

Previous crop: **Potato (main)**

Current crop: **Carrot**

Expected mkt yield t/ha: **67.0 (commercial)**

Maximum mkt yield t/ha: **90.0 (pre-strawing)**

Maximum total DW t/ha: **11.5(pre-strawing)**

Summary of N recommendations (kgN/ha) and calculated yields (t/ha):

Method	Optimum*	RB209	Farm [§]	WELL_N:				SUNDIAL-FRS:			
				Predictive		Retrospective		Predictive		Retrospective	
				Default weather	Actual weather	Default weather	Actual weather	Default weather	+ spring SMN	Actual weather	+ spring SMN
Recommendation	0	25	170	50	50	50	50	0	0	0	0
Calculated yield *	85.8	85.8	N/A	85.8	85.8	85.8	85.8	85.8	85.8	85.8	85.8
% difference from optimum yield		0		0	0	0	0	0	0	0	0

* Calculated as mean trial yield, as there was no significant response to N within the range of the trial.

§ Farm recommendation is actual rate used.

Comments: There was no response of marketable fresh weight or total dry weight yields to applied N at either the pre-strawing (15 October 1998) or commercial (20 January 1999) harvests. Due to the unknown effect of the straw covering on soil temperature, it was not feasible to make predictions beyond the pre-strawing harvest. Farm practice on this sandy soil was to use a high rate of N in an attempt to improve skin quality a characteristic not assessed in the trial. WELL_N recommendations were based on the expected yield at the pre-strawing harvest, when foliage and roots were present and were higher than required. SUNDIAL-FRS correctly recommended that no fertiliser N should be applied.

Crop N uptake and Soil Mineral N (SMN, nitrate plus ammonium) at harvest (kgN/ha)

N rate*	Crop N uptake	Soil 0-30cm	Soil 30-60cm	Soil 60-90cm	Crop N + SMN
Measured values					
0	134	39	17	N/A	190
125	147	40	45	N/A	231
170 (farm) [§]	N/A	N/A	N/A	N/A	
WELL_N Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	101	14	14	N/A	129
125	184	14	17	N/A	215
SUNDIAL-FRS Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	70	3	2	N/A	75
125	85	15	37	N/A	137

Zero and maximum rates used in trial, plus farm rate[§] where available.

Comments: Measured and simulated values are for the pre-strawing harvest. WELL_N underestimated crop N uptake at zero but overestimated at the maximum rate. WELL_N tended to underestimate SMN. SUNDIAL underestimated crop N at harvest.

APPENDIX B

Site reference: 26

Year: 1998

Topsoil texture: **Loamy sand**

Previous crop: **Crisp lettuce**

Current crop: **Leek**

Expected mkt yield t/ha: **33.6**

Maximum mkt yield t/ha: **40.8**

Maximum total DW t/ha: **7.2**

Summary of N recommendations (kgN/ha) and calculated yields (t/ha):

Method	Optimum*	RB209	Farm [§]	WELL_N:				SUNDIAL-FRS:			
				Predictive		Retrospective		Predictive		Retrospective	
				Default weather	Actual weather	Default weather	Actual weather	Default weather	+ spring SMN	Actual weather	+ spring SMN
Recommendation	See below	150+	205	150	125	150	100	340	460	340	460
Calculated yield *			37.3	35.9	35.2	35.9	34.5	40.2	41.4	40.2	41.4
% difference from optimum yield											

* Calculated from linear plus exponential curve fitted to trial data.

§ Farm recommendation is actual rate used.

Comments: A linear response, with the optimum apparently above the maximum (375 kg N/ha) N rate used. With spring SMN measurements, the SUNDIAL-FRS recommendation was increased by 120 kgN/ha. From the response trial, WELL_N appeared to be underestimating requirement, but from a successful strip trial at this site, the WELL_N predictive rate yielded 41.7 t/ha, compared to 34.4 t/ha at the farm rate. This suggests considerable spatial variability cross the site.

Crop N uptake and Soil Mineral N (SMN, nitrate plus ammonium) at harvest (kgN/ha)

N rate*	Crop N uptake	Soil 0-30cm	Soil 30-60cm	Soil 60-90cm	Crop N + SMN
Measured values					
0	139	61	51	20	271
375	272	43	39	11	365
(farm) [§]	N/A	N/A	N/A	N/A	
WELL_N Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	59	18	14	14	105
375	173	27	14	14	228
SUNDIAL-FRS Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	50	6	10	8	73
375	331	12	34	8	385

Zero and maximum rates used in trial, plus farm rate[§] where available.

Comments: SUNDIAL-FRS considerably underestimated crop N and SMN where no fertiliser N had been applied, but gave a good simulation at the maximum N rate, apart from SMN at 0-30cm. WELL_N underestimated at both rates.

APPENDIX B

Site reference: 26

Year: 1999

Topsoil texture: **Loamy sand**
 Current crop: **Crisp lettuce**
 Maximum mkt yield t/ha: **38.0**

Previous crop: **Leek**
 Expected mkt yield t/ha: **33.6**
 Maximum total DW t/ha: **2.6**

Summary of N recommendations (kgN/ha) and calculated yields (t/ha):

Method	Optimum*	RB209	Farm [§]	WELL_N:				SUNDIAL-FRS:			
				Predictive		Retrospective		Predictive		Retrospective	
				Default weather	Actual weather	Default weather	Actual weather	Default weather	+ spring SMN	Actual weather	+ spring SMN
Recommendation	50 (±5)	160	195	100	100	100	100	N/A	N/A	N/A	N/A
Calculated yield *	35.2	36.1	36.4	35.6	35.6	35.6	35.6				
% difference from optimum yield		3	3	1	1	1	1				

* Calculated from linear plus exponential curve fitted to trial data. Estimated standard error given in brackets.

§ Farm recommendation is actual rate used.

Comments: Farm practice and RB209 overestimated N requirement in the presence of leek residues. The WELL_N recommendation was within 1% of the optimum calculated yield.

SUNDIAL-FRS was not able to provide a recommendation for this crop.

Crop N uptake and Soil Mineral N (SMN, nitrate plus ammonium) at harvest (kgN/ha)

N rate*	Crop N uptake	Soil 0-30cm	Soil 30-60cm	Soil 60-90cm	Crop N + SMN
Measured values					
0	83	25	22	24	154
250	106	157	45	27	335
(farm) [§]	N/A	N/A	N/A	N/A	
WELL_N Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	53	16	17	15	101
250	109	154	21	15	299
SUNDIAL-FRS Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	N/A	N/A	N/A	N/A	
250	N/A	N/A	N/A	N/A	

Zero and maximum rates used in trial, plus farm rate[§] where available.

Comments: WELL_N gave reasonable estimates of crop and soil N.

APPENDIX B

Site reference: 27

Year: 1998

Topsoil texture: **Humose loamy sand** Previous crop: **Winter wheat**
 Current crop: **Carrot** Expected mkt yield t/ha: **97 (commercial)**
 Maximum mkt yield t/ha: **82.2 (pre-strawing)** Maximum total DW t/ha: **12.7 (pre-strawing)**

Summary of N recommendations (kgN/ha) and calculated yields (t/ha):

Method	Optimum*	RB209	Farm [§]	WELL_N:				SUNDIAL-FRS:			
				Predictive		Retrospective		Predictive		Retrospective	
				Default weather	Actual weather	Default weather	Actual weather	Default weather	+ spring SMN	Actual weather	+ spring SMN
Recommendation	0	60	30	25	25	25	25	40	0	40	0
Calculated yield *	79.7	79.7	79.7	79.7	79.7	79.7	79.7	79.7	79.7	79.7	79.7
% difference from optimum yield											

* Calculated as mean trial yield, as there was no significant response to N within the range of the trial

§ Farm recommendation is actual rate used.

Comments: There was no response of marketable fresh weight or total dry weight yields to applied N at either the pre-strawing (28 October 1998) or commercial (9 March 1999) harvests. Due to the unknown effect of the straw covering on soil temperature, it was not feasible to make predictions beyond the pre-strawing harvest. WELL_N recommendations based on dry weight yields at the pre-strawing harvest, when foliage and roots were present, were good. Using spring SMN measurements as a diagnostic improved the SUNDIAL-FRS recommendation.

Crop N uptake and Soil Mineral N (SMN, nitrate plus ammonium) at harvest (kgN/ha)

N rate*	Crop N uptake	Soil 0-30cm	Soil 30-60cm	Soil 60-90cm	Crop N + SMN
Measured values					
0	96	39	36	17	188
125	132	49	45	16	242
(farm) [§]	N/A	N/A	N/A	N/A	
WELL_N Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	113	14	14	14	155
125	199	14	14	14	241
SUNDIAL-FRS Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	76	3	5	3	87
125	77	6	22	11	116

Zero and maximum rates used in trial, plus farm rate[§] where available.

Comments: Measured and simulated values are for the pre-strawing harvest. WELL_N correctly estimated crop N uptake at the zero rate but overestimated at the maximum rate. WELL_N underestimate SMN in the 0-60 cm layers. As in Site 25/98, SUNDIAL underestimates crop N at harvest.

APPENDIX B

Site reference: 28

Year: 1998

Topsoil texture: **Silt loam**
 Current crop: **Cauliflower**
 Maximum mkt yield t/ha: **31.0**

Previous crop: **Cauliflower**
 Expected mkt yield t/ha: **29.7**
 Maximum total DW t/ha: **5.7**

Summary of N recommendations (kgN/ha) and calculated yields (t/ha):

Method	Optimum*	RB209	Farm [§]	WELL_N:				SUNDIAL-FRS:			
				Predictive		Retrospective		Predictive		Retrospective	
				Default weather	Actual weather	Default weather	Actual weather	Default weather	+ spring SMN	Actual weather	+ spring SMN
Recommendation	149 (±24)	250	190	175	175	200	200	190	180	190	100
Calculated yield *	28.3	30.4	29.5	29.1	29.1	29.7	29.7	29.5	29.2	29.5	25.9
% difference from optimum yield		7	4	3	3	5	5	4	3	4	-9

* Calculated from linear plus exponential curve fitted to trial data. Estimated standard error given in brackets.

§ Farm recommendation is actual rate used.

Comments: The estimate of the optimum had a high standard error (± 24). WELL_N and farm practice were close to one standard error from optimum, with RB209 overestimating. Retrospective recommendation from WELL_N were 25 kgN/ha higher than predictive since conversion of marketable fresh weight to dry weight 20% higher than expected from model default.

With the original SUNDIAL-FRS cauliflower parameters, the crop was only able to take up 18% of the total N requirement, so the recommendation and calculated yields were far too low. The parameters have now been modified, with much improved results. The presented recommendations are for the new parameters, but the results are not used in the final evaluation of the SUNDIAL recommendations.

Crop N uptake and Soil Mineral N (SMN, nitrate plus ammonium) at harvest (kgN/ha)

N rate*	Crop N uptake	Soil 0-30cm	Soil 30-60cm	Soil 60-90cm	Crop N + SMN
Measured values					
0	82	28	21	31	162
375	223	79	41	31	374
(farm) [§]	N/A	N/A	N/A	N/A	
WELL_N Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	58	38	25	21	142
375	239	136	31	21	427
SUNDIAL-FRS Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	20	13	29	22	84
375	198	193	29	22	443

Zero and maximum rates used in trial, plus farm rate[§] where available.

Comments: The new SUNDIAL-FRS cauliflower parameters gave much improved simulation of crop N uptake, although it was still underestimated at the zero N rate. WELL_N gave reasonable agreement with crop and soil N.

APPENDIX B

Site reference: 28

Year: 1999

Topsoil texture: **Silt loam**
 Current crop: **Cauliflower**
 Maximum mkt yield t/ha: **29.0**

Previous crop: **Cauliflower**
 Expected mkt yield t/ha: **29.7**
 Maximum total DW t/ha: **6.3**

Summary of N recommendations (kgN/ha) and calculated yields (t/ha):

Method	Optimum*	RB209	Farm [§]	WELL_N:				SUNDIAL-FRS:			
				Predictive		Retrospective		Predictive		Retrospective	
				Default weather	Actual weather	Default weather	Actual weather	Default weather	+ spring SMN	Actual weather	+ spring SMN
Recommendation	161 (±9.9)	250	210	175	150	200	175	200	180	180	180
Calculated yield *	24.6	25.8	25.6	25.0	24.3	25.4	25.0	25.4	25.1	25.1	25.1
% difference from optimum yield		5	4	1	-1	3	1	3	2	2	2

* Calculated from linear plus exponential curve fitted to trial data.

§ Farm recommendation is actual rate used.

Comments: WELL_N and farm practice were within 50 kgN/ha of the calculated optimum. As in the previous year, the retrospective recommendation from WELL_N was 25 kgN/ha higher than predictive due to the conversion of marketable fresh weight to dry weight being 20% higher than expected from model default.

With the improved cauliflower parameters (see Site 28/98), the SUNDIAL-FRS recommendation with SMN was within 20 kgN/ha of the optimum. The presented recommendations are for the new parameters, but the results are not used in the final evaluation.

Crop N uptake and Soil Mineral N (SMN, nitrate plus ammonium) at harvest (kgN/ha)

N rate*	Crop N uptake	Soil 0-30cm	Soil 30-60cm	Soil 60-90cm	Crop N + SMN
Measured values					
0	118	27	15	19	179
375	208	236	16	25	485
(farm) [§]	N/A	N/A	N/A	N/A	
WELL_N Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	142	21	14	43	220
375	258	199	51	43	551
SUNDIAL-FRS Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	35	19	55	45	154
375	159	260	55	45	519

Zero and maximum rates used in trial, plus farm rate[§] where available.

Comments: WELL_N overestimated crop N uptake. As in the previous year, the new SUNDIAL-FRS cauliflower parameters gave much improved simulation of crop N uptake, although it was still underestimated at the zero N rate.

APPENDIX B

Site reference: 29

Year: 1998

Topsoil texture: **Silt loam** Previous crop: **Winter wheat**
 Current crop: **Brussels sprout** Expected mkt yield t/ha: **17.9**
 Maximum mkt yield t/ha: **25.0** Maximum total DW t/ha: **10.6**

Summary of N recommendations (kgN/ha) and calculated yields (t/ha):

Method	Optimum*	RB209	Farm [§]	WELL_N:				SUNDIAL-FRS:			
				Predictive		Retrospective		Predictive		Retrospective	
				Default weather	Actual weather	Default weather	Actual weather	Default weather	+ spring SMN	Actual weather	+ spring SMN
Recommendation	352	300	300	300	300	300	300	320	300	300	300
Calculated yield *	21.5	19.9	19.9	19.9	19.9	19.9	19.9	20.6	19.9	19.9	19.9
% difference from optimum yield		-8	-8	-8	-8	-8	-8	-4	-8	-8	-8

* Calculated from linear plus exponential curve fitted to trial data.

§ Farm recommendation is actual rate used.

Comments: The maximum marketable yield was 40% greater than expected due to one high yielding replicate. WELL_N and SUNDIAL-FRS gave similar recommendations, 50kgN/ha less than the optimum, but closer to the expected yield than yield at the optimum N rate. Using actual yields and weather had no effect on the recommendations.

Crop N uptake and Soil Mineral N (SMN, nitrate plus ammonium) at harvest (kgN/ha)

N rate*	Crop N uptake	Soil 0-30cm	Soil 30-60cm	Soil 60-90cm	Crop N + SMN
Measured values					
0	50	21	20	20	111
425	332	24	19	16	391
(farm) [§]	N/A	N/A	N/A	N/A	
WELL_N Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	89	17	15	16	137
425	351	22	14	14	401
SUNDIAL-FRS Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	40	12	41	22	115
425	449	9	21	24	502

Zero and maximum rates used in trial, plus farm rate[§] where available.

Comments: SUNDIAL-FRS overestimated crop N uptake at the maximum rate, leading to the simulated crop N + SMN being over 100 kg N / ha higher than observed. SUNDIAL-FRS gave a good simulation of crop N and SMN at the zero N rate. WELL_N gave reasonable simulations at both rates.

APPENDIX B

Site reference: 30

Year: 1998

Topsoil texture: **Silt loam**

Previous crop: **Cabbage**

Current crop: **Red beet**

Expected mkt yield t/ha: **37.7**

Maximum mkt yield t/ha: **46.3**

Maximum total DW t/ha: **10.9**

Summary of N recommendations (kgN/ha) and calculated yields (t/ha):

Method	Optimum*	RB209	Farm §	WELL_N:				SUNDIAL-FRS:			
				Predictive		Retrospective		Predictive		Retrospective	
				Default weather	Actual weather	Default weather	Actual weather	Default weather	+ spring SMN	Actual weather	+ spring SMN
Recommendation	See below	250	190	125	150	125	150	N/A	N/A	N/A	N/A
Calculated yield *		46.3	38.8	37.5	38.0	37.5	38.0				
% difference from optimum yield											

* Calculated from linear plus exponential curve fitted to trial data.

§ Farm recommendation is actual rate used.

Comments: There was a linear response to applied N and no optimum could be fitted. WELL_N recommended less than either RB209 or farm practice. In a successful strip trial at this site there was no difference in marketable yield between the WELL_N predicted rate and farm practice.

SUNDIAL-FRS is not parameterised for red beet.

Crop N uptake and Soil Mineral N (SMN, nitrate plus ammonium) at harvest (kgN/ha)

N rate*	Crop N uptake	Soil 0-30cm	Soil 30-60cm	Soil 60-90cm	Crop N + SMN
Measured values					
0	217	27	16	13	273
250	345	154	28	22	549
(farm)§					
WELL_N Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	133	14	14	39	200
250	284	14	14	14	326
SUNDIAL-FRS Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	N/A	N/A	N/A	N/A	
250	N/A	N/A	N/A	N/A	

Zero and maximum rates used in trial, plus farm rate§ where available.

Comments: WELL_N underestimated crop N uptake at both rates and SMN at the high rate.

APPENDIX B

Site reference: 30

Year: 1999

Topsoil texture: **Silt loam** Previous crop: **Red beet**
 Current crop: **Savoy cabbage** Expected mkt yield t/ha: **25.0**
 Maximum mkt yield t/ha: **27.0** Maximum total DW t/ha: **10.0**

Summary of N recommendations (kgN/ha) and calculated yields (t/ha):

Method	Optimum*	RB209	Farm [§]	WELL_N:				SUNDIAL-FRS:			
				Predictive		Retrospective		Predictive		Retrospective	
				Default weather	Actual weather	Default weather	Actual weather	Default weather	+ spring SMN	Actual weather	+ spring SMN
Recommendation	298	275	130	250	250	250	250	N/A	N/A	N/A	N/A
Calculated yield *	23.8	23.1	15.1	22.2	22.2	22.2	22.2				
% difference from optimum yield		-3	-36	-7	-7	-7	-7				

* Calculated from linear plus exponential curve fitted to trial data.

§ Farm recommendation is actual rate used.

Comments: Farm practice rate was particularly low - possibly a top-dressing went unrecorded on the non-trial area. Savoy cabbage is not specifically parameterised in WELL_N, but the crop was successfully simulated using Dutch white cabbage parameters.

SUNDIAL-FRS is not parameterised for red beet (the previous crop) or Savoy cabbage.

Crop N uptake and Soil Mineral N (SMN, nitrate plus ammonium) at harvest (kgN/ha)

N rate*	Crop N uptake	Soil 0-30cm	Soil 30-60cm	Soil 60-90cm	Crop N + SMN
Measured values					
0	186	35	20	15	256
400	411	55	57	32	555
(farm) [§]	N/A	N/A	N/A	N/A	
WELL_N Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	141	14	14	14	183
400	342	24	14	16	396
SUNDIAL-FRS Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	N/A	N/A	N/A	N/A	
400	N/A	N/A	N/A	N/A	

Zero and maximum rates used in trial, plus farm rate[§] where available.

Comments: WELL_N underestimated crop N uptake at both rates.

APPENDIX B

Site reference: 31

Year: 1998

Topsoil texture: **Silt loam** Previous crop: **Winter wheat**
 Current crop: **Brussels sprout** Expected mkt yield t/ha: **17.0**
 Maximum mkt yield t/ha: **22.0** Maximum total DW t/ha: **13.0**

Summary of N recommendations (kgN/ha) and calculated yields (t/ha):

Method	Optimum*	RB209	Farm [§]	WELL_N:				SUNDIAL-FRS:			
				Predictive		Retrospective		Predictive		Retrospective	
				Default weather	Actual weather	Default weather	Actual weather	Default weather	+ spring SMN	Actual weather	+ spring SMN
Recommendation	See below	210	265	250	250	300	300	280	240	300	300
Calculated yield *											
% difference from optimum yield											

* Calculated from linear plus exponential curve fitted to trial data.

§ Farm recommendation is actual rate used.

Comments: The optimum was above the maximum (400 kgN/ha) rate used. RB209, farm practice and both models underestimated N requirement. Underestimation by the models used predictively was due, at least in part, to an expected marketable yield 23% less than actually achieved. Used retrospectively, with the actual maximum yield, the SUNDIAL and WELL_N recommendations increased, but were still less than the maximum rate used. It is probable that peak dry matter production had occurred before harvest, prior to loss of mature leaves.

Crop N uptake and Soil Mineral N (SMN, nitrate plus ammonium) at harvest (kgN/ha)

N rate*	Crop N uptake	Soil 0-30cm	Soil 30-60cm	Soil 60-90cm	Crop N + SMN
Measured values					
0	111	27	17	10	165
400	384	32	19	13	448
(farm) [§]	N/A	N/A	N/A	N/A	
WELL_N Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	124	14	14	14	166
400	375	21	14	14	424
SUNDIAL-FRS Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	116	9	9	9	143
400	466	11	12	17	505

Zero and maximum rates used in trial, plus farm rate[§] where available.

Comments: WELL_N simulated crop N and SMN well. SUNDIAL-FRS gave a good simulation at the zero N rate, but overestimated crop N at the maximum N rate.

APPENDIX B

Site reference: 31

Year: 1999

Topsoil texture: **Silt loam** Previous crop: **Brussels sprout**
 Current crop: **Autumn cauliflower** Expected mkt yield t/ha: **17.0**
 Maximum mkt yield t/ha: **17.0** Maximum total DW t/ha: **7.0**

Summary of N recommendations (kgN/ha) and calculated yields (t/ha):

Method	Optimum*	RB209	Farm [§]	WELL_N:				SUNDIAL-FRS:			
				Predictive		Retrospective		Predictive		Retrospective	
				Default weather	Actual weather	Default weather	Actual weather	Default weather	+ spring SMN	Actual weather	+ spring SMN
Recommendation	See below	210	265	250	250	300	300	100	80	120	120
Calculated yield *											
% difference from optimum yield											

* Calculated from linear plus exponential curve fitted to trial data.

§ Farm recommendation is actual rate used.

Comments: No response curve was fitted as only one replicate was harvested because of soil waterlogging on part of the trial. The SUNDIAL-FRS recommendation is low compared to RB209, the farm and WELL_N, and is not used in the overall evaluation of SUNDIAL, as the cauliflower parameters were modified as a result of the initial poor simulation of crop N uptake (see Site 28/98).

Crop N uptake and Soil Mineral N (SMN, nitrate plus ammonium) at harvest (kgN/ha)

N rate*	Crop N uptake	Soil 0-30cm	Soil 30-60cm	Soil 60-90cm	Crop N + SMN
Measured values					
0	73	24	12	14	123
350	295	118	28	16	457
(farm) [§]	N/A	N/A	N/A	N/A	
WELL_N Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	148	14	14	14	190
350	277	47	95	33	452
SUNDIAL-FRS Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	20	37	73	21	151
350	109	173	54	21	357

Zero and maximum rates used in trial, plus farm rate[§] where available.

Comments: Measured values based on single replicate due to waterlogging. SUNDIAL underestimated crop N uptake, in spite of the improved crop parameters. It compensated by overestimating SMN, although crop N + SMN at the maximum N rate was still underestimated.

APPENDIX B

Site reference: 32

Year: 1998

Topsoil texture: **Silt loam** Previous crop: **Brussels sprout**
 Current crop: **Dutch white cabbage** Expected mkt yield t/ha: **97.5**
 Maximum mkt yield t/ha: **82.2** Maximum total DW t/ha: **15.4**

Summary of N recommendations (kgN/ha) and calculated yields (t/ha):

Method	Optimum*	RB209	Farm [§]	WELL_N:				SUNDIAL-FRS:			
				Predictive		Retrospective		Predictive		Retrospective	
				Default weather	Actual weather	Default weather	Actual weather	Default weather	+ spring SMN	Actual weather	+ spring SMN
Recommendation	198	190	260	300	300	325	325	420	420	300	280
Calculated yield *	72.7	72.1	77.2	79.6	79.6	80.9	80.9	N/A	N/A	79.6	78.4
% difference from optimum yield		-1	6	9	9	11	11			9	8

* Calculated from linear plus exponential curve fitted to trial data.

§ Farm recommendation is actual rate used.

Comments: The calculated optimum had a high standard error (± 37). Both WELL_N and SUNDIAL-FRS recommendations were consistently above the optimum, but did result in high yields. It was not possible to calculate yields for the SUNDIAL predictive recommendation, as the recommendation was well above the trial maximum (350 kg N/ha). The SUNDIAL retrospective plus SMN, using the optimum yield, reduced the recommendation, but it was still 80 kgN/ha above the optimum.

Crop N uptake and Soil Mineral N (SMN, nitrate plus ammonium) at harvest (kgN/ha)

N rate*	Crop N uptake	Soil 0-30cm	Soil 30-60cm	Soil 60-90cm	Crop N + SMN
Measured values					
0	231	31	23	17	302
350	431	99	47	19	596
(farm) [§]	N/A	N/A	N/A	N/A	
WELL_N Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	134	19	14	16	183
350	363	19	14	14	410
SUNDIAL-FRS Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	58	11	37	26	132
350	372	22	41	26	461
(farm) [§]					

Zero and maximum rates used in trial, plus farm rate[§] where available.

Comments: Both WELL_N and SUNDIAL-FRS underestimated crop N and SMN at this site.

APPENDIX B

Site reference: 33

Year: 1998

Topsoil texture: **Sandy loam**
 Current crop: **Dwarf bean**
 Maximum mkt yield t/ha: **20.7**

Previous crop: **Salad onion**
 Expected mkt yield t/ha: **19.0**
 Maximum total DW t/ha: **5.2**

Summary of N recommendations (kgN/ha) and calculated yields (t/ha):

Method	Optimum*	RB209	Farm [§]	WELL_N:				SUNDIAL-FRS:			
				Predictive		Retrospective		Predictive		Retrospective	
				Default weather	Actual weather	Default weather	Actual weather	Default weather	+ spring SMN	Actual weather	+ spring SMN
Recommendation	0	100	86	175	175	175	175	N/A	N/A	N/A	N/A
Calculated yield *	19.1	19.1	19.1	19.1	19.1	19.1	19.1				
% difference from optimum yield											

* Calculated as mean trial yield, as there was no significant response to N within the range of the trial

§ Farm recommendation is actual rate used.

Comments: There was no significant response to applied N in the trial. RB209, farm practice and, particularly WELL_N overestimated N requirement, but without loss of yield. The previous salad onion crop had been unharvested and ploughed in 5 days prior to drilling the beans. It is possible that the timing of breakdown of the onion residues had been incorrectly simulated.

SUNDIAL-FRS is not parameterised for salad onion or dwarf beans.

Crop N uptake and Soil Mineral N (SMN, nitrate plus ammonium) at harvest (kgN/ha)

N rate*	Crop N uptake	Soil 0-30cm	Soil 30-60cm	Soil 60-90cm	Crop N + SMN
Measured values					
0	118	42	22	27	209
250	189	149	35	29	402
(farm) [§]	N/A	N/A	N/A	N/A	
WELL_N Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	37	14	32	23	106
250	125	89	32	23	269
SUNDIAL-FRS Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	N/A	N/A	N/A	N/A	
250	N/A	N/A	N/A	N/A	
(farm) [§]					

Zero and maximum rates used in trial, plus farm rate[§] where available.

Comments: WELL_N underestimated crop N uptake and SMN, leading to the overestimate of N requirement.

APPENDIX B

Site reference: 34

Year: 1998

Topsoil texture: **Silty clay loam** Previous crop: **Calabrese**
 Current crop: **Autumn cauliflower** Expected mkt yield t/ha: **31.0**
 Maximum mkt yield t/ha: **23.0** Maximum total DW t/ha: **4.5**

Summary of N recommendations (kgN/ha) and calculated yields (t/ha):

Method	Optimum*	RB209	Farm [§]	WELL_N:				SUNDIAL-FRS:			
				Predictive		Retrospective		Predictive		Retrospective	
				Default weather	Actual weather	Default weather	Actual weather	Default weather	+ spring SMN	Actual weather	+ spring SMN
Recommendation	123	130	112	175	175	175	175	160	180	80	100
Calculated yield *	16.7	16.9	16.5	17.5	17.5	17.5	17.5	17.3	17.6	15.6	16.2
% difference from optimum yield		1	-1	5	5	5	5	4	5	-7	-3

* Calculated from linear plus exponential curve fitted to trial data.

§ Farm recommendation is actual rate used.

Comments: Maturity of this autumn cauliflower variety was delayed into the New Year by cool growing conditions. Not being frost hardy, the trial and commercial crop were both affected by frost damage. The calculated optimum and recommendations were made on the assumption that frosted heads had been marketable, nevertheless, yields were lower than expected and WELL_N overestimated N requirement. A planned top-dressing by the farmer was omitted because of wet soil conditions.

SUNDIAL-FRS is not parameterised for calabrese (the previous crop), so cauliflower was used. Modified cauliflower parameters (see Site 28/98) resulted in much improved crop N uptake. The retrospective recommendation plus SMN was within 25 kgN/ha of the optimum.

Crop N uptake and Soil Mineral N (SMN, nitrate plus ammonium) at harvest (kgN/ha)

N rate*	Crop N uptake	Soil 0-30cm	Soil 30-60cm	Soil 60-90cm	Crop N + SMN
Measured values					
0	116	34	23	11	184
375	184	41	24	49	298
(farm) [§]	N/A	N/A	N/A	N/A	
WELL_N Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	65	19	19	22	125
375	198	19	31	105	353
SUNDIAL-FRS Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	17	9	18	9	52
375	112	23	221	10	366

Zero and maximum rates used in trial, plus farm rate[§] where available.

Comments: WELL_N underestimated crop N uptake at zero, and overestimated SMN in the porous chalk 60-90 cm layer at the high rate of N. The SUNDIAL simulations with modified cauliflower parameters were much improved, although crop N uptake was still underestimated, leading to an accumulation of SMN in the 30-60cm soil layer.

APPENDIX B

Site reference: 34

Year: 1999

Topsoil texture: **Silt loam** Previous crop: **Aut. cauliflower**
 Current crop: **Autumn cauliflower** Expected mkt yield t/ha: **31.0**
 Maximum mkt yield t/ha: **11.0** Maximum total DW t/ha: **2.5**

Summary of N recommendations (kgN/ha) and calculated yields (t/ha):

Method	Optimum*	RB209	Farm [§]	WELL_N:				SUNDIAL-FRS:			
				Predictive		Retrospective		Predictive		Retrospective	
				Default weather	Actual weather	Default weather	Actual weather	Default weather	+ spring SMN	Actual weather	+ spring SMN
Recommendation	0	250	115	75	75	0	0	160	120	120	120
Calculated yield *	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.7
% difference from optimum yield											

* Calculated as mean trial yield, as there was no significant response to N within the range of the trial

§ Farm recommendation is actual rate used.

Comments: As a consequence of a high spring soil mineral N content from the previous crop residue (Table 7), there was no significant response to applied N. The trial crop was harvested slightly immature to avoid frost damage, and as a result the expected yield was not achieved and the predictive recommendation of WELL_N, together with RB209 and farm practice, was too high. Retrospectively, with the low achieved yield, WELL_N correctly recommended a zero N application.

The SUNDIAL recommendations were based on the improved cauliflower parameters (see Site 28/98). They were far too high, even with the spring SMN measurements and a reduced yield in the retrospective runs.

Crop N uptake and Soil Mineral N (SMN, nitrate plus ammonium) at harvest (kgN/ha)

N rate*	Crop N uptake	Soil 0-30cm	Soil 30-60cm	Soil 60-90cm	Crop N + SMN
Measured values					
0	147	12	8	4	171
300	217	50	35	7	309
(farm) [§]	N/A	N/A	N/A	N/A	
WELL_N Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	119	47	49	27	242
300	119	209	179	35	542
SUNDIAL-FRS Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	1	112	35	15	162
300	64	270	35	15	384

Zero and maximum rates used in trial, plus farm rate[§] where available.

Comments: WELL_N underestimated crop N uptake but overestimated SMN. SUNDIAL was unable to simulate crop N uptake by cauliflower, even with the improved crop parameters, so large amounts of fertiliser N accumulated in the soil at the maximum N rate. Yields were rather low at this site (compare with site 28).

APPENDIX B

Site reference: 35

Year: 1998

Topsoil texture: **Silt loam**
 Current crop: **Crisp lettuce**
 Maximum mkt yield t/ha: **24.7**

Previous crop: **Crisp lettuce**
 Expected mkt yield t/ha: **43.7**
 Maximum total DW t/ha: **2.4**

Summary of N recommendations (kgN/ha) and calculated yields (t/ha):

Method	Optimum*	RB209	Farm [§]	WELL_N:				SUNDIAL-FRS:			
				Predictive		Retrospective		Predictive		Retrospective	
				Default weather	Actual weather	Default weather	Actual weather	Default weather	+ spring SMN	Actual weather	+ spring SMN
Recommendation	60	120	125	100	75	100	75	N/A	N/A	N/A	N/A
Calculated yield *	24.0	24.4	24.4	24.5	24.3	24.5	24.3				
% difference from optimum yield		2	2	2	1	2	1				

* Calculated from linear plus exponential curve fitted to trial data.

§ Farm recommendation is actual rate used.

Comments: Crop harvested about 1 week early at farmer's request in order to clear the trial area before the commercial harvest. Consequently the crop had not achieved its expected weight and the calculated optimum was lower than it might otherwise have been.

SUNDIAL-FRS was unable to provide a recommendation for this crop.

Crop N uptake and Soil Mineral N (SMN, nitrate plus ammonium) at harvest (kgN/ha)

N rate*	Crop N uptake	Soil 0-30cm	Soil 30-60cm	Soil 60-90cm	Crop N + SMN
Measured values					
0	86	36	37	36	195
275	107	292	146	119	664
(farm) [§]	N/A	N/A	N/A	N/A	
WELL_N Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	78	14	18	38	148
275	102	92	157	49	400
SUNDIAL-FRS Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	N/A	N/A	N/A	N/A	
275	N/A	N/A	N/A	N/A	

Zero and maximum rates used in trial, plus farm rate[§] where available.

Comments: WELL_N predicted crop uptake reasonably well but underestimated SMN

APPENDIX B

Site reference: 36

Year: 1998

Topsoil texture: **Peat**

Previous crop: **Carrot**

Current crop: **Crisp lettuce**

Expected mkt yield t/ha: **43.7**

Maximum mkt yield t/ha: **42.0**

Maximum total DW t/ha: **3.0**

Summary of N recommendations (kgN/ha) and calculated yields (t/ha):

Method	Optimum*	RB209	Farm §	WELL_N:				SUNDIAL-FRS:			
				Predictive		Retrospective		Predictive		Retrospective	
				Default weather	Actual weather	Default weather	Actual weather	Default weather	+ spring SMN	Actual weather	+ spring SMN
Recommendation	81	100	100	100	100	75	75	N/A	N/A	N/A	N/A
Calculated yield *	43.3	43.5	43.5	43.5	43.5	43.0	43.0				
% difference from optimum yield		1	1	1	1	-1	-1				

* Calculated from linear plus exponential curve fitted to trial data.

§ Farm recommendation is actual rate used.

Comments: WELL_N has not previously been used on peat soils due to uncertainties in mineralisation rate. Using an estimate of mineralisation based on measured changes in pre- and post-cropping soil mineral N on the zero N plots, good estimates of the calculated optimum were achieved both predictively and retrospectively. These results were not used in the evaluation of the model, however, as the mineralisation value was not independent of the data.

SUNDIAL-FRS is not parameterised for peat soils.

Crop N uptake and Soil Mineral N (SMN, nitrate plus ammonium) at harvest (kgN/ha)

N rate*	Crop N uptake	Soil 0-30cm	Soil 30-60cm	Soil 60-90cm	Crop N + SMN
Measured values					
0	67	37	36	108	248
250	109	281	80	105	539
(farm)§	N/A	N/A	N/A	N/A	
WELL_N Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	80	14	27	30	151
250	122	162	46	30	360
SUNDIAL-FRS Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	N/A	N/A	N/A	N/A	
250	N/A	N/A	N/A	N/A	

Zero and maximum rates used in trial, plus farm rate§ where available.

Comments: WELL_N gave reasonable estimates of crop N uptake but underestimated SMN.

APPENDIX B

Site reference: 36

Year: 1999

Topsoil texture: **Peat**

Previous crop: **Crisp lettuce**

Current crop: **2nd early potato**

Expected mkt yield t/ha: **62.8**

Maximum mkt yield t/ha: **55.0**

Maximum total DW t/ha: **11.0**

Summary of N recommendations (kgN/ha) and calculated yields (t/ha):

Method	Optimum*	RB209	Farm §	WELL_N:				SUNDIAL-FRS:			
				Predictive		Retrospective		Predictive		Retrospective	
				Default weather	Actual weather	Default weather	Actual weather	Default weather	+ spring SMN	Actual weather	+ spring SMN
Recommendation	202	130	230	175	175	100	100	N/A	N/A	N/A	N/A
Calculated yield *	52.6	45.9	52.4	50.6	50.6	42.5	42.5				
% difference from optimum yield		-13	-1	-4	-4	-19	-19				

* Calculated from linear plus exponential curve fitted to trial data.

§ Farm recommendation is actual rate used.

Comments: Achieved marketable yields were lower than expected, due to a high percentage (up to 10%) of rejected green tubers. Using a calculated mineralisation rate (see site 36/98), WELL_N gave a reasonably good predictive estimate of the optimum. Total dry weight yield was also lower than expected and use of WELL_N retrospectively gave an underestimate of optimum. These results were not used in the evaluation of the model, however, as the mineralisation value was not independent of the data.

SUNDIAL-FRS is not parameterised for peat soils.

Crop N uptake and Soil Mineral N (SMN, nitrate plus ammonium) at harvest (kgN/ha)

N rate*	Crop N uptake	Soil 0-30cm	Soil 30-60cm	Soil 60-90cm	Crop N + SMN
Measured values					
0	61	57	24	75	217
250	148	68	53	68	337
(farm)§	N/A	N/A	N/A	N/A	
WELL_N Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	123	14	14	33	184
250	254	14	14	36	318
SUNDIAL-FRS Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	N/A	N/A	N/A	N/A	
250	N/A	N/A	N/A	N/A	

Zero and maximum rates used in trial, plus farm rate§ where available.

Comments: WELL_N overestimated crop N uptake and underestimated SMN.

APPENDIX B

Site reference: 37

Year: 1998

Topsoil texture: **Clay loam**
 Current crop: **Salad onion**
 Maximum mkt yield t/ha: **25.0**

Previous crop: **Winter wheat**
 Expected mkt yield t/ha: **23.0**
 Maximum total DW t/ha: **2.1**

Summary of N recommendations (kgN/ha) and calculated yields (t/ha):

Method	Optimum*	RB209	Farm [§]	WELL_N:				SUNDIAL-FRS:			
				Predictive		Retrospective		Predictive		Retrospective	
				Default weather	Actual weather	Default weather	Actual weather	Default weather	+ spring SMN	Actual weather	+ spring SMN
Recommendation	18	125	129	125	125	125	125	40	0	20	0
Calculated yield *	19.1	22.1	22.2	22.1	22.1	22.1	22.1	20.1	16.0	19.2	16.0
% difference from optimum yield		16	16	16	16	16	16	5	-16	1	-16

* Calculated from linear plus exponential curve fitted to trial data.

§ Farm recommendation is actual rate used.

Comments: Salad onions are not specifically parameterised in WELL_N and were run as bulb onions, albeit with a lower target yield. With this over-wintered crop, recommendations were made prior to spring top-dressing, following a measurement of plant size. RB209, farm practice and WELL_N recommended rates agreed closely and out-yielded the particularly low calculated optimum by 16%.

SUNDIAL-FRS is not specifically parameterised for salad onions and was also run as bulb onions, with adjustments to the expected yield to take account of the different dry matter contents. The retrospective recommendations used an equivalent yield of 19 t/ha. Recommendations were close to the optimum, but gave a yield penalty in comparison with the WELL_N, RB209 and farm rates.

Crop N uptake and Soil Mineral N (SMN, nitrate plus ammonium) at harvest (kgN/ha)

N rate*	Crop N uptake	Soil 0-30cm	Soil 30-60cm	Soil 60-90cm	Crop N + SMN
Measured values					
0	27	40	40	23	130
200	94	133	47	28	302
(farm) [§]					
WELL_N Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	18	26	19	30	93
200	67	137	26	31	261
SUNDIAL-FRS Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	40	21	24	25	110
200	57	73	111	24	265

Zero and maximum rates used in trial, plus farm rate[§] where available.

Comments: Both WELL_N and SUNDIAL-FRS gave reasonable estimates of crop and soil N, considering that they are not parameterised for salad onion.

APPENDIX B

Site reference: 37

Year: 1999

Topsoil texture: **Clay loam**
 Current crop: **Salad onion**
 Maximum mkt yield t/ha: **9.5**

Previous crop: **Salad onion**
 Expected mkt yield t/ha: **29.0**
 Maximum total DW t/ha: **1.3**

Summary of N recommendations (kgN/ha) and calculated yields (t/ha):

Method	Optimum*	RB209	Farm [§]	WELL_N:				SUNDIAL-FRS:			
				Predictive		Retrospective		Predictive		Retrospective	
				Default weather	Actual weather	Default weather	Actual weather	Default weather	+ spring SMN	Actual weather	+ spring SMN
Recommendation	87	75	175	50	50	0	0	80	0	40	20
Calculated yield *	7.8	7.6	7.6	7.2	7.2	5.9	5.9	7.7	5.9	7.0	6.5
% difference from optimum yield		-2	-2	-7	-7	-24	-24	-1	-24	-10	-17

* Calculated from linear plus exponential curve fitted to trial data.

§ Farm recommendation is actual rate used.

Comments: This Japanese bunching onion (*Allium fistulosum*) yielded considerably less than expected because of a low plant stand due to a cloddy seedbed. There was also considerable spatial variability in yield. This species is not parameterised for WELL_N and was run as bulb onion. Predictive recommendations were within 50 kgN/ha of the calculated optimum but the retrospective recommendations were too low.

SUNDIAL-FRS is not parameterised for salad onions, and so the recommendations were run for bulb onions with adjustments to the expected yield to take account of the different dry matter contents. The SUNDIAL predictive recommendation was very close to the optimum, but the retrospective recommendations were well below the optimum and resulted in a yield penalty.

Crop N uptake and Soil Mineral N (SMN, nitrate plus ammonium) at harvest (kgN/ha)

N rate*	Crop N uptake	Soil 0-30cm	Soil 30-60cm	Soil 60-90cm	Crop N + SMN
Measured values					
0	21	68	48	22	159
200	29	137	73	43	282
(farm) [§]	N/A	N/A	N/A	N/A	
WELL_N Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	48	87	48	32	215
200	48	287	48	32	415
SUNDIAL-FRS Simulation (retrospective with actual weather, actual yields and N rates and spring SMN)					
0	43	11	124	35	213
200	46	11	123	34	214

Zero and maximum rates used in trial, plus farm rate[§] where available.

Comments: WELL_N overestimated crop N uptake and SMN in the 0-30 cm layer. SUNDIAL overestimated crop N, and gave a poor estimation of SMN.