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Grain Yield and the Incidence of Take-all and Eyespot in Winter Wheat Grown in Different Crop Sequences at Saxmundham

D. B. SLOPE, JUDITH ETHERIDGE and R. J. B. WILLIAMS

Winter wheat given adequate fertiliser can be expected to yield 6 t/ha or more of grain on the clay loam over Clay-with-flints (Batcombe Series) at Rothamsted when grown after crops other than cereals, but wheat after wheat often yields 1–3 t/ha less, partly because take-all (*Gaeumannomyces graminis* (Sacc.) Arx & Olivier var. *tritici* Walker, formerly called *Ophiobolus graminis* Sacc.) and eyespot (*Cercosporella herpotrichoides* Fron) become prevalent (Glynne & Slope, 1959; Slope & Etheridge, 1971). This experiment aimed to determine whether similar large yields of wheat could be obtained on the calcareous boulder clay (Beccles Series) soil at Saxmundham in Suffolk, and whether take-all and eyespot were as damaging to wheat grown after wheat as they can be at Rothamsted.

Experiment

The site used consisted of two series of the partly discontinued Rotation II experiment, each containing 10 plots differently fertilised between 1899 and 1952 (Boyd & Trist, 1966). Unfortunately, the two series had carried different crops since 1952. Between 1962 and 1965, before our experiment began, Series A (the site of blocks I and II in our experiment) grew spring oats, winter wheat, spring beans and spring barley in successive years; Series B (blocks III and IV) grew sugar beet, spring barley, winter wheat and spring barley. The barley crop in 1965 had more take-all and yielded less grain on Series B than on Series A. Our experiment, begun in autumn 1965, comprised four replicates of the five cropping sequences shown in Table 1. The plot boundaries coincided with those of the old experiment.

TABLE 1

Crop sequences, 1966–70

	Sequence number				
Year	1	2	3	4	5
1966	Wheat	Ley	Ley	Wheat	Wheat
1967	Wheat	Wheat	Beans	Ley	Wheat
1968	Wheat	Wheat	Wheat	Beans	Ley
1969	Wheat	Wheat	Wheat	Wheat	Beans
1970	Wheat	Wheat	Wheat	Wheat	Wheat

Cappelle-Desprez wheat was sown during October in the years 1965 to 1968, but in early November in 1969. All the wheat plots were split to test three amounts of nitrogen fertiliser: 75, 150, 225 kg N/ha broadcast as 'Nitro-Chalk' during the second half of March each year; the same amounts of nitrogen were applied to the same subplots each year they carried wheat. To counteract possible residual effects of the different fertilisers applied to different plots between 1899 and 1952 large amounts of phosphate and potash fertilisers (125 kg P_2O_5, 125 kg K_2O/ha) were applied to all plots each year, broadcast as a 0 : 20 : 20 compound fertiliser before ploughing in autumn 1966 but after ploughing in other years. The one-year grass leys (Meadow Fescue in 1966, S.22 Italian ryegrass in 1967 and 1968, sown during March) also received 125 kg N/ha broad-

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cast as 'Nitro-Chalk' on the seedbed, and 63 kg N/ha as 'Nitro-Chalk' and 125 kg K_2O/ha as muriate of potash after the first cut. The field beans (*Vicia fabae*) were sown during March each year, and received no extra fertiliser.

Wheat plants were sampled during the second half of June each year when between growth stages 10·1 and 10·5 on the Feekes scale (Large, 1954). The plants were washed and examined for symptoms of take-all, eyespot, and sharp eyespot (*Rhizoctonia solani* Kuhn). Plants with roots attacked by *G. graminis* were graded *slight*, infection mostly confined to seminal roots; *moderate*, up to approximately 75% of all roots infected; or *severe*, more than 75% of roots infected. Few plants were severely attacked. Straws attacked by *C. herpotrichoides* were graded *slight* or *severe*. The area of each crop lodged was estimated during August. The wheat was combine-harvested and grain yields weighed. The sides of the harvested strip were not bounded by unsown paths or blank rows, so yields were not enhanced by so large an edge effect as they are in most Rothamsted experiments (Widdowson, 1972). Yields of grass and beans were not measured.

Results

No effects of the old fertiliser treatments were detected in 1966 when 12 of the 20 plots grew wheat, but the different previous cropping of the two series seemed to affect the incidence of take-all and grain yield of wheat in the years 1966 to 1968. In 1966 wheat had less take-all and yielded more on Series A than on Series B, but in 1967 take-all was less and yields larger on Series B than on Series A. In 1968 yields were similar on both series, though take-all was less on Series B (Table 2).

TABLE 2

Incidence of take-all and grain yield of continuous wheat, sequence 1, 1966–68 (averages of three nitrogen treatments)

Series	Blocks	Cropping 1962–65	1966	1967	1968
			% plants with take-all*		
A	I and II	sO.wW.Be.sB†	47 (25)	81 (49)	49 (18)
B	III and IV	Bt.sB.wW.sB	86 (54)	53 (20)	21 (7)
			Grain (t/ha, 85% DM)		
A	I and II	sO.wW.Be.sB	3·69	3·83	4·57
B	III and IV	Bt.sB.wW.sB	2·97	4·62	4·49

* Numbers without brackets are total infection, within brackets moderate plus severe infection
† Crop symbols: wW = winter wheat, sO = spring oats, sB = spring barley, Be = field beans, Bt = sugar beet

Table 3 shows the grain yield for each wheat crop, averaged for the replicates on both series. Continuous wheat (sequence 1) given only 75 kg N/ha yielded less than wheat after ley in 1967 and after beans in 1968 to 1970. The differences were largest in the two years (1967, 1968) when take-all was most prevalent in the continuous wheat, but extra nitrogen decreased the differences, so even in these years the best yield of the continuous wheat was only 0·8 t/ha less than the best of wheat after ley or beans. In the years when take-all was not prevalent (1969, 1970) best yields did not differ significantly. Thus, during the three years 1968 to 1970 wheat given 75 kg N/ha yielded on average only 0·9 t/ha more after two non-cereal crops than after two or three wheat crops, and only 0·3 t/ha more where given 150 kg N/ha. On average none of the wheat crops yielded more with 225 kg N/ha than with 150 kg N/ha (Table 4).

Crop sequence had little effect on the percentage of nitrogen in grain, except in 1968 when wheat after beans (sequence 3) had more (2·08, 2·30, 2·38% in crops given 75, 150,

TABLE 3

Grain yield (t/ha, 85% DM) of winter wheat grown in five cropping sequences, 1966–70

Year	Nitrogen, kg/ha		Crop sequence 1	2	3	4	5	Mean
1966		Crop:	wW.2/4*	Ley	Ley	wW.2/4	wW.2/4	
	75		2·51	—	—	2·41	2·41	2·43
	150		3·85	—	—	3·56	3·41	3·61
	225		4·02	—	—	4·00	3·84	3·95
	Mean		3·46	—	—	3·32	3·22	
1967		Crop:	wW.3/5	wW.1	Beans	Ley	wW.3/5	
				(V ± 0·192, H ± 0·194)†				(±0·110)
	75		3·46	4·54	—	—	3·56	3·85
	150		4·47	5·48	—	—	4·30	4·76
	225		4·72	4·94	—	—	4·10	4·59
	Mean (±0·114)		4·22	4·99	—	—	3·99	
1968		Crop:	wW.4/6	wW.2	wW.1	Beans	Ley	
				(V ± 0·149, H ± 0·148)				(±0·087)
	75		4·28	4·88	5·81	—	—	4·99
	150		5·03	5·71	5·53	—	—	5·42
	225		4·28	4·87	5·02	—	—	4·73
	Mean (±0·085)		4·53	5·16	5·46	—	—	
1969		Crop:	wW.5/7	wW.3	wW.2	wW.1	Beans	
				(V ± 0·106, H ± 0·126)				(±0·053)
	75		2·61	2·56	3·10	3·31	—	2·89
	150		3·38	3·45	3·98	3·75	—	3·64
	225		3·68	3·63	3·94	3·94	—	3·80
	Mean (±0·091)		3·22	3·21	3·67	3·67		
1970		Crop:	wW.6/8	wW.4	wW.3	wW.2	wW.1	
				(V ± 0·104, H ± 0·136)				(±0·046)
	75		3·26	3·08	3·03	3·29	3·52	3·24
	150		3·60	3·52	3·55	3·75	3·74	3·63
	225		3·81	3·53	3·55	3·86	3·62	3·67
	Mean (±0·107)		3·56	3·37	3·37	3·63	3·63	

* Numbers after crop symbols indicate successive crops suceptible to *G. graminis*. Double numbers are needed for some crops because of the different cropping on the two series before the experiment began

† V for use in vertical and interaction comparisons only; H for use in horizontal and diagonal comparisons only

225 kg N/ha respectively) than wheat after wheat (1·74, 2·12, 2·26). So Table 5 shows only the nitrogen uptake in grain averaged for all crop sequences sown to wheat. Nitrogen uptake was much larger in 1968 than in other years, though the best grain yield in 1968 (5·81 t/ha) was only slightly larger than the best in 1967 (5·48 t/ha).

TABLE 4

Yields of grain (t/ha, 85% DM) from first, second and third or fourth crops of wheat after a two-year break of ley, beans; three-year averages, 1968–70

Nitrogen kg/ha	Crop wW.1	wW.2	wW.3 or 4
75	4·22	3·75	3·30
150	4·34	4·48	4·00
225	4·19	4·23	3·82

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TABLE 5

Effect of nitrogen fertiliser on nitrogen uptake (kg/ha) in grain

Year	Fertiliser nitrogen, kg/ha: 75	150	225	Mean
1966	37·8	59·5	67·9	55·2
1967	45·5	61·3	66·2	57·7
1968	79·6	100·4	92·2	90·7
1969	38·6	51·4	60·2	50·1
1970	41·1	49·0	53·6	47·9
Mean	48·5	64·3	68·0	—

TABLE 6

Percentage of area of wheat lodged, 23 August 1968

Nitrogen kg/ha	Crop sequence: 1	2	3
Crop:	wW.4/6	wW.2	wW.1
75	0	0	0
150	0	15	80
225	75	75	100

TABLE 7

Percentage of plants with take-all in June on winter wheat grown in five cropping sequences, 1966–70

Year	Nitrogen, kg/ha		Crop sequences: 1	2	3	4	5
1966		Crop:	wW.2/4*	Ley	Ley	wW.2/4	wW.2/4
	75		76 (48)†	—	—	83 (59)	63 (40)
	150		65 (38)	—	—	68 (42)	72 (43)
	225		50 (18)	—	—	63 (37)	57 (28)
	Mean		64 (35)	—	—	71 (46)	64 (37)
1967		Crop:	wW.3/5	wW.1	Beans	Ley	wW.3/5
	75		68 (35)	11 (3)	—	—	Not sampled
	150		76 (41)	13 (4)	—	—	
	225		58 (29)	12 (2)	—	—	
	Mean		67 (35)	12 (3)	—	—	
1968		Crop:	wW.4/6	wW.2	wW.1	Beans	Ley
	75		41 (19)	16 (5)	2 (0)	—	—
	150		29 (6)	14 (4)	5 (2)	—	—
	225		34 (11)	11 (2)	2 (1)	—	—
	Mean		35 (12)	14 (4)	3 (1)	—	—
1969		Crop:	wW.5/7	wW.3	wW.2	wW.1	Beans
	75		8 (1)	21 (5)	18 (7)	1 (0)	—
	150		4 (1)	11 (2)	19 (8)	0	—
	225		7 (1)	41 (16)	9 (1)	0	—
	Mean		6 (1)	24 (8)	15 (5)	0	—
1970		Crop:	wW.6/8	wW.4	wW.3	wW.2	wW.1
	75		9 (2)	11 (1)	27 (4)	16 (3)	0
	150		5 (0)	9 (0)	20 (3)	11 (1)	1 (0)
	225		5 (0)	8 (1)	13 (1)	6 (0)	1 (0)
	Mean		6 (1)	9 (1)	20 (3)	11 (1)	1 (0)

* Numbers after crop symbols indicate successive crops susceptible to *G. graminis*. Double numbers are needed for some crops because of the different cropping on the two series before the experiment began.

† Numbers without brackets are total infection, within brackets moderate plus severe infection

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Lodging was extensive only in 1968 (Table 6) when the largest amount of nitrogen significantly decreased yield on all sequences sown to wheat. In other years lodging was not enough to limit grain yield or response to nitrogen fertiliser.

Table 7 shows that take-all was common in continuous wheat (sequence 1) in 1966, 1967 and, less so, 1968, though the amount differed on the two series (Table 2). In 1969 and 1970 the continuous wheat had very little take-all, less than the third successive wheats (sequence 2 in 1969, sequence 3 in 1970). However, in these two years most of the take-all symptoms were slight. The effects of different amounts of nitrogen fertiliser on the incidence of take-all were inconsistent.

Eyespot was common on wheat after wheat only in 1968 (Table 8), when it probably decreased the yield of wheat on Sequence 1, though its effect on yield cannot be separated from that of take-all. In other years eyespot in wheat after wheat averaged less than 15% of straws infected, and most was slight. As expected, eyespot was unimportant on wheat after two crops not susceptible to *C. herpotrichoides*.

TABLE 8

Percentage of straws with eyespot in winter wheat, June 1968

Nitrogen, kg/ha		Crop sequence 1	2	3
	Crop:	wW.4/6	wW.2	wW.1
75		58 (37)*	37 (19)	7 (3)
150		41 (22)	20 (10)	5 (2)
225		40 (20)	9 (4)	5 (3)
Mean		46 (26)	22 (11)	6 (3)

* Numbers without brackets are total infection, within brackets severe infection

Sharp eyespot was most common in 1970, but even then no crop had more than 10% of straws attacked, and most lesions did not penetrate deeply into the straw. Mildew (*Erysiphe graminis* f.sp. *tritici*) was severe on the upper leaves of wheat given 225 kg N/ha and, less so, on wheat given 150 kg N/ha in 1966, 1968 and 1970. Infection was also severe during early summer in 1969, but the later leaves were only lightly attacked. In 1967 many upper leaves were attacked by yellow rust (*Puccinia striiformis*), especially in crops given most nitrogen. These foliar diseases were not assessed precisely, but their attacks probably decreased grain yield and responses to nitrogen fertiliser. In 1966 the wheat was severely infested during spring by larvae of the dipterous shoot-boring insect *Opomyza florum*, and many plants and primary tillers were killed.

Discussion

Wheat yielded up to 5·5 t/ha after ley in 1967, and 5·8 t/ha after beans in 1968, but less than 4 t/ha after beans in 1969 and 1970. Thus, at Saxmundham, we did not consistently achieve the large yields usually obtained from wheat grown after a break crop at Rothamsted, but our results do not explain why. As expected, take-all and eyespot were unimportant in the wheat after ley or beans, and we did not recognise any other soil-borne pathogen known to limit yield seriously. Attacks by foliar pathogens, especially *E. graminis*, were probably more severe than they usually are at Rothamsted, but they were as severe in 1967 and 1968, when yields were large, as in 1969 and 1970 when yields were small, so foliar diseases alone are unlikely to account for the small yields. No serious attacks by insect pests were recorded, except that by *O. florum* in 1966. This was much more damaging than attacks by this pest at Rothamsted (Slope,

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1957), probably because wheat at Saxmundham, even when sown early (the 1966 crop was sown on 8 October), tillers much less during late autumn and winter than wheat at Rothamsted.

The soil at Saxmundham is difficult to cultivate, and structure problems often occur. Partly because of this, the effects of weather can be large. Three periods are critical. Wet autumns make cultivations especially difficult, the soil becomes compacted and the seedbeds are cloddy, adversely affecting establishment and early growth of autumn sown crops. Heavy rain after applying nitrogen in spring may leach much nitrogen. Drought in summer can be very damaging because roots of annual crops do not penetrate deeply in the Saxmundham soil, so available water is soon exhausted. These problems have been discussed in detail by Williams (1971), and by Cooke and Williams (1972). The Appendix gives brief notes on weather and measurements of nitrate-N in drainage and in plant tissue during the 4 years (1967–70) when we grew wheat after ley or beans, and suggests ways in which weather may have influenced wheat yields.

It seems that weather and soil conditions were favourable enough for wheat free from soil-borne diseases to give acceptable yields in 1967 and 1968, but not in 1969 or 1970. However, the conditions that favoured wheat seemed also to favour take-all, so the differences between yields of wheat after wheat and wheat after ley or beans were largest when yields were large. Even so, wheat after wheat in 1967 and 1968 yielded more than wheat after beans in 1969 and 1970. It seems that yield of wheat at Saxmundham was more seriously affected by weather and soil conditions than by take-all and eyespot. Nevertheless, our results show that take-all can cause serious loss of yield in wheat after wheat. They also show that 'take-all decline' (Slope & Cox, 1964) may occur at Saxmundham, as at Rothamsted, when several crops susceptible to *G. graminis* are grown in succession. The effect of this on the yields of wheat grown on the two series of the old Rotation II experiment (Table 2) illustrates the importance of doing wheat experiments only on sites uniformly cropped for several years previously.

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References

Boyd, D. A. & Trist, P. J. O. (1966) The Saxmundham rotation experiments: rotation II, 1899–1952. *Journal of Agricultural Science, Cambridge* **66**, 337–339.

Cooke, G. W. & Williams, R. J. B. (1972) Problems with cultivations and soil structure at Saxmundham. *Rothamsted Experimental Station. Report for 1971*, Part 2, 122–142.

Glynne, M. D. & Slope, D. B. (1959) Effects of previous wheat crops, seed-rate and nitrogen on eyespot, take-all, weeds and yields of two varieties of winter wheat. *Annals of Applied Biology* **47**, 187–199.

Large, E. C. (1954) Growth stages in cereals. *Plant Pathology* **3**, 128–129.

Slope, D. B. (1957) *Opomyza florum* on early-sown winter wheat. *Plant Pathology* **6**, 110.

Slope, D. B. & Cox, J. A. (1964) Continuous wheat growing and the decline of take-all. *Rothamsted Experimental Station. Report for 1963*, 108.

Slope, D. B. & Etheridge, J. (1971) Grain yield and incidence of take-all (*Ophiobolus graminis* Sacc.) in wheat grown in different crop sequences. *Annals of Applied Biology* **67**, 13–22.

Widdowson, F. V. (1973) Results from experiments with wheat and barley measuring the effects of paths on yield. *Experimental Husbandry* No. 23, 16–21.

Williams, R. J. B. (1969) Nitrate in crops and drainage at Saxmundham. *Rothamsted Experimental Station. Report for 1968*, Part 1, 49–52.

Williams, R. J. B. (1971) The chemical composition of water from land drains at Saxmundham and Woburn, and the influence of rainfall upon nutrient losses. *Rothamsted Experimental Station. Report for 1970*, Part 2, 36–67.

Williams, R. J. B. & Cooke, G. W. (1972) Experiments on herbage crops at Saxmundham, 1967–71. *Rothamsted Experimental Station. Report for 1971*, Part 2, 95–121.

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APPENDIX

Notes on crop growth, weather, soil conditions and losses of nitrate-N in drainage, 1967–70

From 1966 weather records for Saxmundham have been published in the Rothamsted Annual Reports. Drainage flows are totals of the four drains serving the experimental field at Saxmundham; the locations of these has been described by Williams (1971).

1967 season. September 1966 was dry, seedbeds were rough, and wheat established slowly. Spring 1967 was warm and wheat grew well. Following 16 mm of rain on 10 April, 30 ppm of nitrate-N were measured in drainage; on 6 May, after 31 mm of rain during the previous five days, there were nearly 50 ppm nitrate-N in drainage. However, total drainage and loss of nitrate-N during spring were only moderate. June, July and August had long dry periods, but with occasional heavy showers, so the wheat grew well and gave moderate yields.

1968 season. Average rainfall during autumn 1967 enabled satisfactory seedbeds and crop establishment to be achieved, but rain was heavy between early January and mid February; between 14 and 22 mm fell on each of four separate days. Afterwards there was little heavy rain until the beginning of May, and none during 10 days in April. On 6 May, 18 mm fell; this caused some drainage (60 litre/minute) containing about 70 ppm nitrate-N. However, total rainfall between January and May was less than average, and small soil moisture contents measured during April and May indicate that little of the fertiliser nitrogen applied in March was lost by leaching. Some heavy rain fell during June, July and August, but there were also dry periods, so total drainage flows were small (<7 litre/minute) and contained little nitrate-N. Measurements of nitrate-N in stem tissues during June indicated that the wheat had enough nitrogen (Williams, 1969), and it grew well throughout the summer. Indeed, wheat given 150 or 225 kg N/ha lodged severely for the only year during the experiment, and grain yield responses to nitrogen fertiliser were small. It is unlikely that yield was limited by lack of nitrogen or water, and yields of wheat after beans were the largest achieved during the experiment.

1969 season. September 1968 was exceptionally wet (138 mm of rain), though October to December was drier than average. Cultivations during late September and early October consolidated the very wet soil, and seedbeds were poor, which may have accentuated the effect of heavy rain (92 mm) during May 1969, 46 mm of which fell in amounts exceeding 10 mm/day. On 6 May drainage flows were 330 litre/minute, and the drainage contained 70 ppm of nitrate-N. Flows on 19 and 30 May were smaller (30 litre/minute) and contained less nitrate-N (30 ppm), nevertheless the total loss of nitrogen by leaching during May was large. The soil remained wet, and drainage persisted into July. Flows unusually large (35 litre/minute) for summer drainage occurred on 28 July, but the water contained little nitrate-N, suggesting that much nitrogen had been lost earlier. Wheat plants from crops given 150 kg N/ha in March had no nitrate in stem tissue by 12 June, but plants from crops given 225 kg N/ha still contained some nitrate-N at the beginning of July. The extra 75 kg N/ha increased grain yield by 0·3 t/ha. Nitrate-N concentrations in wheat after beans were no larger than those in wheat after wheat. The serious leaching of nitrogen from soil during late spring may account for the small grain yields obtained in 1969.

1970 season. September and October 1969 were exceptionally dry (only 9 mm of rain fell during the two months), but satisfactory seedbeds and crop establishment were

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achieved. Winter rainfall was above average. Following the application of nitrogen fertiliser on 19 March, rainfall was average to the end of April, but fell as showers of less than 5 mm/day. Drainage flowrates and nitrate-N concentration (<20 ppm) were much less than in 1969. May to August were exceptionally dry, only 75 mm of rain fell during the four months, all in small amounts separated by long periods of hot dry weather. There was no drainage during July and August, and very little during May and June (<2 litre/minute), which contained only about 5 ppm nitrate-N. During the summer, accumulated soil moisture deficits increased quickly (Williams & Cooke, 1972), and soil 5 cm deep often reached 32°C, indicating how dry the soil was, and perhaps explaining why plants had difficulty in acquiring nitrogen. Much nitrogen, unused by crops during the summer, was leached when drains began to flow again in November, when drainage contained unusually large concentrations of nitrate-N (up to 57 ppm). Lack of soil moisture, and the effect this had on immobilising nitrogen, probably partly explains the poor growth and grain yield of wheat in 1970.

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