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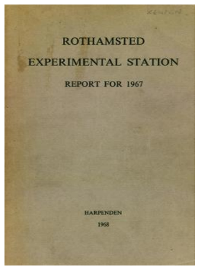

Woburn Experimental Station

C. A. Thorold

C. A. Thorold (1968) *Woburn Experimental Station ;* Rothamsted Report For 1967, pp 259 - 264 **- DOI: https://doi.org/10.23637/ERADOC-1-120**

WOBURN EXPERIMENTAL STATION

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The winter was mild, with mean temperatures above average in December, January and February, and snow fell on only two days in November and on one in January. More than average rain in April and much more in May (Table 1) hampered field work and leached nitrogen and lime, one of the many problems of light-land farming studied at Woburn. Soil-borne pests and diseases were again prevalent, especially in potatoes and sugar beet, and means of controlling them are being sought, indirectly by crop rotation and directly by pesticides.

TABLE 1

Monthly mean temperatures (means of maximum and minimum), total rainfall and daily means of bright sunshine (departures from long-period means in brackets)

	Mean temperature (° C)	Rainfall (in.)	Bright sunshine (daily mean) (hours)
March	7·3 (+1·8)	1·30 (−0·28)	5·69 (+1·85)
April	7·4 (−0·8)	2·42 (+0·49)	3·83 (−1·31)
May	10·3 (−0·9)	4·27 (+2·07)	5·45 (−0·58)
June	13·3 (−1·1)	1·35 (−0·35)	7·16 (+0·57)
July	17·1 (+0·8)	1·65 (−0·79)	7·33 (+1·37)
August	15·8 (−0·2)	1·23 (−1·10)	4·98 (−0·73)
September	12·3 (−1·4)	2·13 (+0·10)	3·34 (−1·19)
October	10·9 (+1·1)	4·47 (+2·17)	3·17 (−0·09)

Three times as many *Myzus persicae* were trapped as in 1966; most were caught in June (43%) and July (45%), when sugar beet became generally affected with yellows. Nearly ten times as many winged *Aphis fabae* (1242) were trapped as in 1966 (134).

The casual and subjective observations of air pollution made since 1929, when the local Oxford Clay began to be used for making bricks, were replaced in March by continuous daily sampling of the air for sulphur dioxide and smoke, to study possible effects on the soil and crops.

Irrigation experiments

Spring wheat. Kloka spring wheat drilled on 7 March was sprayed with CCC (2-chloroethyltrimethyl-ammonium chloride) at 2·5 lb/acre on 23 May. A wet May (22 rain days) was followed by a dry period until 19 June, during which ears emerged. CCC shortened straw (27·3 in. with and 38·7 in. without), but it did not entirely prevent lodging in one of the irrigated plots. Table 2 shows that the largest yield of grain (47·2 cwt/acre) without irrigation was given by 0·8 cwt N/acre, and with irrigation by 1·2 cwt N. Straw yield increased from 33 to 58 cwt with a 4-fold increase in

https://doi.org/10.23637/ERADOC-1-120

amount of nitrogen. Water seemed not to be a limiting factor, because straw yields on unwatered plots increased with all increases in nitrogen, whereas with irrigation the maximum straw yield (59·8 cwt) was reached at 1·2 cwt N/acre. Premature ripening, which is considered below, may have limited the effect of nitrogen on yield of grain.

TABLE 2

Grain and straw yields of spring wheat

"Nitro-Chalk" (N, cwt/acre)	Without Irrigation Grain (cwt/acre)	Without Irrigation Straw (cwt/acre)	With Irrigation* Grain (cwt/acre)	With Irrigation* Straw (cwt/acre)	Mean Grain (cwt/acre)	Mean Straw (cwt/acre)
0·4	35·7	31·6	39·2	35·2	37·5	33·4
0·8	47·2	47·8	51·5	52·8	49·4	50·3
1·2	42·9	50·5	53·9	59·8	48·4	54·9
1·6	38·4	51·5	49·9	59·8	44·1	57·8
Mean	41·0	45·3	48·6	51·9	44·8	49·1

* Irrigation: June, 2·0 in.; July, 2·0 in.

Potatoes. Table 3 shows the consequences of growing the varieties Pentland Dell (susceptible to potato cyst-nematode) and Maris Piper (resistant) alternately and successively in 1966 and 1967 in plots with initially differing populations of the nematode. Some plots were irrigated, and some were fumigated with the nematicide "D-D" at 400 lb/acre.

TABLE 3

Yields from potato varieties susceptible and resistant to potato cyst-nematode on two sites, one lightly and one heavily infested initially, some plots fumigated, some irrigated (total tubers tons/acre and ware percentage)

Degree of infestation	Sequence of varieties	Without Irrigation				With Irrigation*			
		Pentland Dell		Maris Piper		Pentland Dell		Maris Piper	
		0	F†	0	F†	0	F†	0	F†
First year (1966)									
Light		16·2	17·2	19·4	20·0	11·9	15·6	16·1	18·5
		95%	95%	94%	95%	90%	94%	89%	95%
Heavy		8·9	14·0	13·0	16·5	6·6	12·5	11·0	14·4
		80%	93%	90%	96%	67%	91%	86%	93%
Second year (1967)									
Light	Same	6·1	10·5	11·7	12·8	5·7	13·5	10·3	14·7
		83%	96%	92%	93%	84%	95%	89%	91%
	Alternating	10·1	14·5	8·1	11·8	10·4	17·8	9·2	14·5
		94%	96%	94%	94%	95%	97%	94%	96%
Heavy	Same	0·8	3·3	5·1	10·9	1·1	5·3	6·5	13·6
		67%	80%	84%	92%	61%	87%	85%	92%
	Alternating	3·6	7·5	4·7	10·5	4·1	11·2	5·2	14·7
		79%	91%	92%	97%	83%	93%	91%	97%

* Irrigation: June (2·0 in.); July (2·0 in.); August (0·25 in.).
† Fumigation (F): 400 lb/acre "D-D" injected at intervals 6 in. apart in rows 12 in. apart, in period 21 November to 5 December 1967, after similar treatment in 1966.
(O): No "D-D".

In 1966, without "D-D" or irrigation, Pentland Dell yielded 8·9 ton tubers/acre on the more heavily infested land. When grown again on this land in 1967 it yielded only 0·8 ton tubers/acre. With fumigation it yielded

https://doi.org/10.23637/ERADOC-1-120

3·3 ton tubers/acre, less than a quarter of the yield in 1966. Where Maris Piper was grown in 1966, Pentland Dell yielded 10 ton/acre, without fumigation or irrigation, more than 14 tons with fumigation and 17 tons with both. Table 4 summarises the effects of the treatments.

TABLE 4

Mean effects of crop sequences, fumigation and irrigation on yields of ware tubers (ton/acre)

Degree of infestation initially	Crop sequences				Un-fumigated	Fumigated	Un-irrigated	Irri-gated	Mean
	*SS	†RR	SR	RS					
Light	8·0	11·3	10·3	12·6	8·1	13·0	9·9	11·1	10·5
Heavy	1·9	8·0	8·3	5·7	3·1	8·8	5·0	6·6	5·8
Mean	4·9	9·7	9·3	9·2	5·6	10·9	7·5	8·9	8·3

* S, susceptible Pentland Dell. † R, resistant Maris Piper.

Smallest mean yields on lightly and heavily infested land were when Pentland Dell was grown both years and largest when Maris Piper was grown both years. Irrigation had little effect compared with fumigation or growing a resistant variety, and differed between the two years; on average it decreased yields by about 2·5 ton/acre in 1966 and increased them by 1·4 tons in 1967. On most plots where Maris Piper was grown in both years fumigation greatly increased yields, perhaps because cyst eelworm was still plentiful enough either to be directly damaging or to enhance the effects of another pathogen such as *Verticillium dahliae*, or perhaps because "D-D" also killed other injurious organisms, such as ectoparasitic nematodes.

Another experiment sought to cheapen fumigation by placing small amounts of nematicide into potato ridges shortly before planting (see p. 155). Yet others will test new nematicides, broadcast or placed, and the benefits of nematicides through a rotation of crops. (Jones, Parrott and Thorold)

The lightly infested site used for the irrigation–fumigation trial previously carried a long ley and then lucerne for 2 years, whereas the heavily infested site had carried arable crops. The potatoes after ley and lucerne were severely scabbed (*Streptomyces scabies*); almost 40% of the surface of the tubers carried lesions, whether or not the land was treated with "D-D". Although irrigation almost halved the area of tubers scabbed, it did not start until the middle of June, too late to be fully effective. "D-D" applied at 0, 1, 2 and 4 ml/ft of ridge in another experiment again had no effect on the percentage of tuber surface scabbed. (Lapwood and Thorold)

Direct-seeding experiment. A continuation of the experiment started in 1965 (*Rothamsted Report* for 1966, p. 271) compared conventional drilling of winter wheat (Cappelle) after ploughing on 30 September 1966 with slit-seeding into unploughed spring-wheat stubble sprayed twice with paraquat (27 September and 25 October). The seed was combine-drilled with PK fertiliser (0:14:28 at 560 lb/acre) on 27 October. All plots were top-dressed with "Nitro-Chalk" (448 lb/acre) on 24 April. The plant stand in the slit-seeded plots became very gappy in January, probably damaged by

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slugs, mainly the "field slug" (*Agriolimax reticulatus*). The straw litter on the surface of unploughed plots seemingly provided conditions that favoured slugs, for plants on ploughed plots were not damaged. Rainfall during November, December and January slightly exceeded average, and although November was colder than average, December and January were warmer. The soil at 4 in. depth was above freezing in November, December and January except for one week (4–11 January), conditions in which *Agriolimax reticulatus* moves and feeds. Immediately before combining on 22 August, the crop cover was estimated on all plots, from complete stand (100%) to absence of crop (0%). Table 5 shows average percentage of cover, yields and amount of lodging in ploughed and unploughed plots.

TABLE 5

Winter wheat drilled in ploughed and unploughed land

	Ploughed land	Land unploughed, treated with herbicide
Crop cover (0%–100%)	97·6%	53·9%
Yield (cwt grain/acre)	59·2	44·7
Lodging (0–3)	1·1	0·2

Dates of sowing spring wheat. Effects of dates of sowing and of applying nitrogen on the incidence of take-all were again tested (*Rothamsted Report* for 1966, p. 271). Kloka wheat, sown on three dates (15 February, 14 March, 17 April), was given 0·8 cwt N/acre, either all at sowing or half at sowing and half on 12 May. Mean soil temperatures between 1st and 2nd sowings and between 2nd and 3rd sowings were 40·1° F and 42·6° F. Lower leaves became very yellow early in the year, presumably reflecting nitrogen deficiency. This did not happen in 1966, and yields were smaller in 1967 (Table 6). Plots were scored for appearance on 29 May and awarded

TABLE 6

Spring wheat yields in 1966 and 1967 (grain cwt/acre)

"Nitro-Chalk" (N, cwt/acre)	Month of sowing: February		March		April		Mean	
	1966	1967	1966	1967	1966	1967	1966	1967
0·8 (at sowing)	30·4	25·2	33·0	22·7	33·7	19·4	32·3	22·4
0·4 + 0·4 (at sowing + May)	30·1	27·3	33·8	22·7	31·7	19·7	31·9	23·3
Mean	30·2	26·3	33·4	22·7	32·7	19·6	32·1	22·9

marks from 6 (green) to 0 (severe yellowing). The mean scores for the six treatments were 5·7 and 3·3 for the earliest sowing with divided and single N dressings; 5·3 and 3·7 for the intermediate sowing with divided and undivided dressings; 4·0 and 3·0 for the latest sowing with divided and undivided dressings. The wheat ripened prematurely, as also did wheat and barley in other experiments. Take-all was not prevalent in 1966, and samples taken to assess its incidence in 1967 have yet to be examined.

Air pollution observations. Fumes from brickworks contain sulphur oxides and can damage the leaves of a wide range of species. Susceptibility of different arable crops differs, with lucerne and barley very sensitive,

https://doi.org/10.23637/ERADOC-1-120

potato relatively resistant, and wheat and sugar beet intermediate. Some plants, but seemingly not wheat or barley, are especially sensitive to fluorides, which the fumes also contain and which can accumulate in herbage, and injure livestock that eat it (Webster, C.C *The effects of air pollution on plants and soil.* H.M.S.O. (A.R.C.) (1967), pp. 14, 18 and 27).

Woburn Experimental Farm is near the Central Bedfordshire Brickfield and lies about 1 mile south of the south-western extremity of the "Brickfields Valley", which extends in a north-easterly direction towards Bedford. Consequently, winds from the north and north-east are commonly characterised by the offensive, but otherwise seemingly harmless odours that accompany the harmful sulphur oxides and fluorine compounds in the gases from the kilns.

Warren Spring Laboratory installed a prototype directional sampler to test its performance. An optical switching device in the wind vane allows it to sample pollution when the wind is blowing in different directions, and a limit switch in the anemometer circuit allows it to sample in calm weather. Wind speed and direction readings are taken once a minute and recorded on magnetic tape for processing on a computer.

Pollution was sampled from: (*a*) a south-easterly sector from open country; (*b*) a westerly sector, including Husborne Crawley village about ¾ mile distant; (*c*) a northerly sector including the brickworks; (*d*) in calm weather. Sulphur dioxide concentrations increased from about 30 $\mu g/m^3$ when the wind blew from the direction of the village to 160 $\mu g/m^3$ when the wind blew from the brickworks. The instrument operated from 14 July to 3 November 1967, a period when northerly winds were rare.

The Woburn Sands and District Preservation and Protection Society have initiated studies of gaseous effluents in the neighbourhood, and thanks to them, air pollution is now measured daily with a volumetric smoke and sulphur dioxide apparatus installed in March. Results are published in the Warren Spring Laboratory's National Survey of Smoke and Sulphur Dioxide Monthly Summaries.

TABLE 7

Sulphur dioxide concentration ($\mu g/m^3$)

Month	March	April	May	June	July	August
Maximum	134	208	141	532	104	122
Average	28	81	37	85	44	50

Table 7 summarises provisional results, given as averages of all the daily concentrations and largest daily concentrations of sulphur dioxide ($\mu g/m^3$) for March to August.

As expected, north-easterly winds were associated with air pollution exceeding the "background" values, from nil to about 30 $\mu g/m^3$ of SO_2. Wind directions were observed visually at 9·00 h, 15·00 h and 21·00 h G.M.T. Values of sulphur dioxide were greatest in April and June, and there were periods of 9 days in both months (7 to 15 April; 10 to 18 June) when there were north-easterly winds on 20 and 21 of the 27 possible observation times (74% and 78%). Previous records show that north-easterly winds are likely in April but are unusual in June, which was therefore exceptional in 1967. Sulphur dioxide concentrations then reached

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532 $\mu g/m^3$ (Table 7), which is near the "first tolerance limit" for wheat (572–858 $\mu g/m^3$) as given by Webster (p. 19). June is a critical time because cereal ears emerge then and cereals are likely to be especially sensitive to sulphur dioxide.

On 27 June many flag leaves of wheat in the Irrigation Experiment became discoloured, starting with the leaf tips becoming yellow or brown, and the whole leaf later turning brown or reddish brown. No pathogen seemed associated with this condition, and mildew at that time was confined to the lower leaves, so that stems had a central zone with seemingly healthy leaves. Later mildew spread to upper leaves. On 22 July there were few green leaves remaining in unwatered plots, but nearby irrigated plots were greener, especially those given most nitrogen.

The upper leaves may have been damaged by sulphur dioxide or some associated effluent. The largest daily concentration (532 $\mu g/m^3$) of SO_2 was on 13 June, and flag leaves became discoloured about a fortnight later, mainly on unirrigated plots, so a water deficit may have been a contributory factor. However, the condition persisted in spite of 1·35 in. of rain between 20 and 26 June. So many leaves were killed by mildew plus the discolouration of uncertain cause that the wheat ripened quickly. Nevertheless, the mean yield in the irrigation experiment was 45 cwt grain/acre, and one irrigated plot given 1·2 cwt N/acre yielded 59 cwt. The smallest yield was 33 cwt grain/acre, without irrigation and with least nitrogen (0·4 cwt N/acre).

https://doi.org/10.23637/ERADOC-1-120