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EFFECT OF DRAINAGE ON CROP YIELD ON BLANKET PEAT

W. Burke

An Foras Talúntais, Soil Physics Department, Kinsealy, Malahide Road, Dublin 5

ABSTRACT

Four crops, *viz.*, two grasses, potatoes, and oats, were grown on blanket peat under different intensities of drainage: 3-in., 1-ft, 2-ft and 3-ft deep drains. Drains were spaced at 10-ft intervals. Water-table depths were monitored in stand pipes in the middle of the plots and a difference in intensity of drainage between treatments was thus demonstrated and measured.

All crops responded to drainage. Yields were higher on drained than on undrained plots. However, with grass, an increase in nitrogen fertiliser application from 4 to 8 cwt per acre eliminated the yield reduction caused by high water tables.

At high nitrogen fertiliser applications (4 cwt per acre) in oats, there was no significant difference in yield between drainage treatments, but severe lodging occurred in well-drained plots. When nitrogen fertiliser was reduced (2 cwt per acre) to eliminate this lodging, a significant difference emerged between drained and undrained plots.

Yields of potatoes were significantly higher on drained than on undrained plots. However, this difference could be explained by the high percentage of failures in the undrained plots.

INTRODUCTION

It has long been accepted that water-table depths in peat affect crop yields, and experiments have been carried out in many countries to measure these effects.

Among the many reports available is that of Nicholson and Firth (1), who studied the effects of ground water depths on crops on fen peat. They reported that for most crops on which they worked the optimum depth to ground water was 2½ to 3 ft, with good results from potatoes and celery at depths of 2 ft. Robertson (2) reported that, at Koningsmoor in Germany, a water-table depth of 40 to 50 cm (16 to 20 in.) was found most suitable for grassland and 70 to 80 cm (28 to 32 in.) best for tillage crops. In Minnesota, Roe (3) obtained best yields of grass with a water table at 45 to 50 cm (18 to 20 in.). In the Florida Everglades (4), several crops yielded highest at water-table depths of 45 to 60 cm (18 to 24 in.), with grass requiring a higher water table, 30 to 60 cm (12 to 24 in.).

In the foregoing investigations, despite differences in climate and properties of the peats, there is good agreement that water-table depths of not less than 2 ft are required for highest crop yields.

Because the climate of the west coast of Ireland and the physical properties of peat there differ from those at the locations of the foregoing experiments, it was considered necessary to determine whether a similar relationship would hold between crop yields and water-table depth. The experiment was carried out at Glenamoy in the west of Ireland. Owing to the low permeability of Glenamoy peat, a very intensive drainage system is needed for water-table control (5, 6), and the cost of drainage will depend on the water-table depth required for crop and grass growth.

EXPERIMENTAL

The surface of most of the blanket peat in the west of Ireland is undulating as it follows fairly closely the contours of the mineral soil lying 4 to 20 ft below. Exact control of

TABLE 1: Water-table depths in ryegrass during growing season

Year	Drain depth (ft)	Average depth to water table (in.)	No. of weeks water table exceeded 12 in.	No. of weeks water table exceeded 18 in.	No. of weeks water table was measured
	0.25	8.4	4	0	
1963	1	10.9	12	0	27
	2	15.1	24	6	
	3	18.2	25	16	
	0.25	8.3	4	0	
1964	1	12.1	18	1	30
	2	16.7	26	16	
	3	19.0	28	22	
	0.25	10.4	8	0	
1965	1	13.4	14	2	20
	2	18.0	19	12	
	3	20.3	20	15	
	0.25	9.0	6	0	
1966	1	13.0	16	2	24
	2	17.6	23	14	
	3	19.7	24	18	
	0.25	9.7	8	0	
1967	1	13.3	18	2	25
	2	17.3	22	14	
	3	19.9	24	18	

TABLE 2 Water-table depths in cocksfoot (1963–64) and in tall fescue (1965–67) during growing season

Year	Drain depth (ft)	Average depth to water table (in.)	No. of weeks water table exceeded 12 in.	No. of weeks water table exceeded 18 in.	No. of weeks water table was measured
	0.25	8.3	4	0	
1963	1	11.0	11	0	27
	2	16.2	25	11	
	3	17.0	24	13	
	0.25	6.7	1	0	
1964	1	11.0	15	0	30
	2	16.7	26	16	
	3	16.2	25	11	
	0.25	8.5	4	0	
1965	1	12.3	12	0	20
	2	17.5	19	10	
	3	18.0	20	12	
	0.25	7.4	1	0	
1966	1	12.2	15	0	24
	2	17.9	23	14	
	3	17.6	23	11	
	0.25	7.7	3	0	
1967	1	12.5	15	1	25
	2	18.3	23	15	
	3	18.1	23	15	

water table in the area is difficult in sloping sites. Annual rainfall at the station is in excess of 50 in. and is uniformly distributed throughout the year. On average, rain falls on about 250 days each year. Potential evaporation from grass is about 18 to 20 in. Because of this constant excess of rainfall, soil moisture deficits are for all practical purposes unknown. The problem at Glenamoy is therefore a drainage one, and the question of keeping the water table up to a specified level has not been considered.

It was therefore decided that drains would be installed to four different depths, *viz:* 3 in., 1 ft, 2 ft, and 3 ft, all at 10-ft spacing. It has already been shown that this spacing is required for water-table control in blanket peat at Glenamoy (5, 6). The function of the 3-in. drains was to ensure that no surface ponding of water took place on any plot. Perennial ryegrass, cocksfoot (later replaced by tall fescue), potatoes and oats were grown on each of the four drainage treatments. The experimental design was a fully randomised block with four replications. Since four crops were under test, there were four experiments in progress on the site. Plots consisted of two sub-sections, each 10 ft × 30 ft. In laying out the experiment, four blocks were marked out. The four drainage treatments were then randomised within each block. Each drainage treatment had nine drains of equal depth giving eight plots in which the four crops were randomised. A 12-ft wide margin separated drainage treatments. Previous experiments (6) had shown that this margin was sufficient. At harvesting, a 2-ft wide margin was discarded from all sections to give a harvested area of 312 sq ft per plot. The experiment was conducted from 1963 to 1967 inclusive. Oats and potatoes were rotated with each other. Perennial ryegrass was grown in the same plots for 5 years without any break. After 1 year the cocksfoot showed severe chlorosis and died off in patches. It was replaced by tall fescue in 1965.

Water-level movement in observation wells lags somewhat behind the true water-table movement in the soil. However, the purpose of this investigation was to measure the effect of drainage depth on crop yields. The depth of water in observation wells in the plots was considered to be a useful indicator of water table and therefore of the degree of drainage achieved by the treatments. Depths were measured in wells in the middle of all plots twice a week during the growing season and once a week in grass plots during winter. For convenience these measurements are referred to as water-table depths.

TABLE 3: Water-table depths in oat crop during growing season

Year	Drain depth (ft)	Average depth to water table (in.)	No. of weeks water table exceeded 12 in.	No. of weeks water table exceeded 18 in.	No. of weeks water table was measured
	0.25	9.6	6	0	
1963	1	12.6	17	2	27
	2	16.9	25	12	
	3	19.0	26	18	
	0.25	8.7	9	0	
1964	1	14.0	22	6	30
	2	16.5	27	18	
	3	20.2	28	20	
	0.25	10.1	7	0	
1965	1	14.2	15	4	20
	2	20.5	20	15	
	3	21.6	20	16	
	0.25	7.6	2	0	
1966	1	12.6	15	2	24
	2	16.7	24	15	
	3	20.7	24	20	
	0.25	8.1	4	0	
1967	1	12.3	15	2	25
	2	15.3	20	16	
	3	20.2	22	18	

TABLE 4: Water-table depths in potato crop during growing season

Year	Drain depth (ft)	Average depth to water table (in.)	No. of weeks water table exceeded 12 in.	No. of weeks water table exceeded 18 in.	No. of weeks water table was measured
	0.25	8.1	4	0	
1963	1	11.7	14	0	27
	2	15.7	25	9	
	3	17.7	25	15	
	0.25	8.6	6	0	
1964	1	12.4	19	2	30
	2	17.2	25	17	
	3	18.1	26	19	
	0.25	9.8	7	0	
1965	1	14.4	16	3	20
	2	18.6	19	13	
	3	19.9	19	14	
	0.25	8.1	1	0	
1966	1	12.0	14	1	24
	2	16.7	22	10	
	3	18.8	23	16	
	0.25	8.3	5	0	
1967	1	11.7	14	1	25
	2	16.3	20	11	
	3	17.3	21	14	

Fertilisers

Before sowing in 1963, all plots received the following basal dressing per acre: 2 tons ground limestone, 4 cwt superphosphate, 2 cwt basic slag, 2 cwt muriate of potash, 3 cwt calcium ammonium nitrate and 28 lb copper sulphate. In the following years the basal dressings per acre were 2 cwt superphosphate, 2 cwt muriate of potash, 2 cwt basic slag and 14 lb copper sulphate.

Calcium ammonium nitrate applications were as follows:

Oats:	1963–64	2 cwt at sowing time+2 cwt in June
	1965–67	1 cwt at sowing time+1 cwt in June
Potatoes:	All years	2 cwt at sowing time+2 cwt on June 1 +2 cwt on July 1
Grasses:	1963–65 (inclusive)	2 cwt in March/April+1 cwt after each of two cuts
	1966–67	2 cwt in March/April+2 cwt after each of three cuts.

TABLE 5: Water-table depths during winter in grass crops

	Average depth to water table (in.) and no. of weeks W.T. exceeded 12 and 18 in.	Perennial ryegrass				Cocksfoot/tall fescue			
		Drain depth (ft)				Drain depth (ft)			
		0.25	1	2	3	0.25	1	2	3
1963–64[a] (20 weeks)	W.T. (in.)	7.1	10.9	15.0	16.6	6.5	11.1	16.3	15.6
	Exceeded 12 in.	1	10	16	17	0	9	17	17
	Exceeded 18 in.	0	1	6	11	0	0	9	7
1964-65[a] (23 weeks)	W.T. (in.)	6.2	9.9	15.0	15.4	4.4	10.6	15.3	17.3
	Exceeded 12 in.	1	9	18	18	0	5	18	20
	Exceeded 18 in.	0	0	9	9	0	0	9	13
1965–66 (31 weeks)	W.T. (in.)	5.4	9.0	13.9	14.6	4.2	9.7	13.6	15.3
	Exceeded 12 in.	0	7	22	23	0	9	22	24
	Exceeded 18 in.	0	0	7	9	0	0	4	11
1966–67 (26 weeks)	W.T. (in.)	5.2	10.4	14.2	16.5	4.3	9.5	14.4	14.4
	Exceeded 12 in.	1	10	19	23	0	7	20	20
	Exceeded 18 in.	0	3	5	11	0	0	6	5

[a] Cocksfoot

RESULTS AND DISCUSSION

Water-table depths

Tables 1 to 4 summarise water-table data during four summers, 1964–67, and Table 5 summarises the winter water-table data from the grass plots. Three criteria have been used to describe the water table:

1. Mean weekly depth of water table below the surface.
2. Number of weeks that mean water-table depth was 12 in. or more below the surface.
3. Number of weeks that mean water-table depth was 18 in. or more below the surface.

The tables show that while mean water-table depth mid-way between drains can be higher or lower than the drain bottom, mean water-table depths increase progressively with drain depths. However, there is very little increase in water-table depth with the 3-ft compared with the 2-ft drains. This type of water-table pattern corresponds with previous results from Glenamoy (5). Galvin has also shown a reduction in permeability of Glenamoy peat following an increase in drain depth from 1 to 3½ ft (7).

Table 5 shows the drainage effect during the winter months. Although the water table on average was higher than in summer, the general drainage effect was the same.

Perennial ryegrass

Table 6 shows the effect of drainage depth on yield of perennial ryegrass. The grass plots were sown in spring 1963. Growth was not very vigorous in the first year and yields were low. There was a significant difference between the plots with 3-in. drainage and the others. In 1964 the crops were fully established and there was a significant difference between yields which were higher than in 1963. Yields increased with drainage depth — the yield with 3-ft drains being 33% higher than with 3-in. and 1-ft drainage and 19% higher than with 2-ft drainage. In 1965, because grass died off in patches, yields were lower than in 1964, but were higher on the better drained plots

TABLE 6: Effect of drainage depth on mean yield of perennial ryegrass (lb dry matter per acre)

Year	Drain depth (ft) 0.25	1	2	3	SE of mean	F-test
1963	3,500	4,300	4,900	4,600	±250	*
1964	7,500	7,600	8,400	10,000	±200	***
1965	4,400	5,500	6,100	6,500	±347	*
1966	10,200	9,700	10,400	10,100	±224	NS
1967	12,200	12,100	11,800	11,600	±360	NS

than on the poorly drained ones. There were symptoms of nitrogen deficiency in 1963-65 inclusive. In 1966 and 1967 nitrogen application on all plots was doubled. High yields were obtained on all plots and yield differences between drainage treatments disappeared.

Thus at low nitrogen levels, drainage significantly affected yields. At higher nitrogen levels, there was no difference. These results suggest that about 160 lb of nitrogen per acre may prevent the yield reduction caused by high water table.

Cocksfoot/tall fescue

Table 7 shows the effect of drainage on yield of cocksfoot and tall fescue. With cocksfoot there was a significant difference between yields at different drainage depths. Plots with 1-ft drains gave 23% higher yield than those with 3-in. drains; the corresponding increase for plots with 2-ft and 3-ft drains was almost 40%. However, the cocksfoot proved difficult to maintain and continued to die out in patches. Because of this, yields were not taken in 1964, and the cocksfoot was replaced by tall fescue in 1965.

Good establishment of tall fescue proved difficult. Although plots were sown in 1965 and weak patches were re-seeded, there was still considerable patchiness in 1966. All plots were vigorous in 1967, but no significant differences in yields occurred (Table 7). However, as in the ryegrass plots, the high nitrogen dressing probably overcame the deleterious effects of high water table.

Oats

Table 8 shows the effect of drainage on yield of oats. Satisfactory yields were obtained in all years on drained plots. In 1963 and 1964 severe lodging occurred on the plots drained at 1 ft, 2 ft and 3 ft while the oats on the 3-in. drainage plots remained standing. Apparently the nitrogen applied was adequate for the 3-in. drainage plots but excessive for the well-drained plots and there was no significant difference in yields. To overcome this lodging, calcium ammonium nitrate application was reduced

TABLE 7: Effect of drainage depth on mean yield of cocksfoot and tall fescue (lb dry matter per acre)

Year	Drain depth (ft) 0.25	1	2	3	SE of mean	F-test
			Cocksfoot			
1963	3,900	4,800	5,500	5,400	±244	**
			Tall fescue			
1966	7,200	8,200	8,300	7,700	±284	NS
1967	11,200	10,800	10,800	10,500	±383	NS

TABLE 8: Effect of drainage depth on mean yield of oats (lb per acre)

Year	Drain depth (ft) 0.25	1	2	3	SE of mean	F-test
1963[a]	3,713	3,602	3,350	3,588	±221	NS
1964[a]	2,380	2,350	2,560	2,870	±304	NS
1965	1,180	2,750	3,100	3,150	±230	***
1966	270	2,510	3,100	3,160	±150	***
1967	210	1,790	2,276	2,480	±208	***

[a] Moisture content of grain assumed to be 20%

TABLE 9: Effect of drainage depth on mean yield of potatoes (cwt tubers per acre)

Year	Drain depth (ft) 0.25	1	2	3	SE of mean	F-test
1963	148	212	238	231	±14.7	**
1964	163	204	231	212	±14.1	*
1965	147	230	246	241	±12.2	***
1966	120	211	216	168	±17.3	*
1967	168	231	255	236	± 7.8	***

from 4 to 2 cwt per acre in 1965, 1966 and 1967. In those 3 years, a highly significant yield reduction was apparent in the 3-in. drainage plots. Yields increased significantly from 1-ft to 2-ft depths, but the difference between 2-ft and 3-ft plots was very small. On 3-in. drainage plots the oats were stunted and did not ripen evenly.

Potatoes

Table 9 shows the effect of drainage on yield of potatoes. Yields were generally good in all except the 3-in. drainage plots which differed significantly from the other plots in all years. There was no significant difference in yield between plots with 1-, 2- and 3-ft drainage although the yield with the 2-ft drains tended to be slightly higher than with the other depths. The low yield with the 3-ft drains in 1966 was attributed to an early severe attack of potato blight. The low yields in the 3-in. drainage plots was due to failure of planted sets. Sets which became established yielded well in the 3-in. drainage treatment, but as all plots were receiving 6 cwt calcium ammonium nitrate per acre, it again appears that this application of nitrogen could compensate for lack of drainage.

TABLE 10: Effect of drainage depth on mean percentage of potato failures

Year	Drain depth (ft) 0.25	1	2	3	SE of mean	F-test
1963	37.0	16.7	7.3	10.1	±3.62	**
1964	41.3	17.8	11.3	14.8	±4.95	*
1965	40.2	7.2	1.0	1.2	±4.83	***
1966	28.4	3.6	2.1	1.7	±1.39	***
1967	25.5	7.4	1.0	2.7	±1.96	***

Seed potato failures

Table 10 shows that drainage significantly affected potato failure. A high proportion of the sets failed on the 3-in. drainage plots and the difference between these plots and the others was significant in all years. A lesser percentage failed on the 1-ft drained plots but this percentage was greater than those on the 2-ft and 3-ft plots. Failures were also higher in earlier than in later years. The failures were largely attributed to the state of the ground at the time of planting. When conditions were wet, there was a high percentage of failures. The reduction in failures in later years may be attributed to better soil structure and aeration due to the amelioration resulting from cultivation and from continual drainage.

The potatoes were grown on the flat. Traditionally, on wet ground in Ireland, potatoes are grown on ridges. The effect of a ridge is to provide better drainage which is particularly important at sowing time when the ground is often wet. It seems reasonable to assume that if the potatoes had been grown on ridges the yield difference between undrained and drained plots would have been much less.

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