Effects of Pig and Cow Slurry on the Growth of Sitka Spruce on Oligotrophic Peat and Gley Soils in Northern Ireland

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Introduction

Nutrients are normally applied to forest crops in the form of organic or inorganic fertilisers. Urea, rock phosphate and potassium chloride are the most commonly used forms of N, P and K respectively in Northern Ireland. There are no important naturally occurring sources of P or K in the province which are suitable for use as fertilisers. Nevertheless agriculture in the province shows a surplus of nutrients (McAllister, 1971) due to the large quantities imported in fertilisers and in feedingstuffs for cattle, pigs and poultry. The input surplus has been estimated at 20 kg P and 25 kg K/ha on agricultural land per year. On the more intensive livestock farms much higher local surpluses of nutrients exist and disposal of the excreta on grassland (which accounts for 90% of all agricultural land) can cause major problems. For example, grazed swards may be damaged or killed by severe scorching as a result of excessive applications of urine with subsequent recolonisation by inferior grasses; excessive dressings of excreta as slurry may produce a slow drying organic layer on the soil surface which renders it more liable to poaching, while the finer solids can block soil pores and restrict aeration; the high levels of potassium which may be built up in the soil increase the risk of hypomagnesaemia; and the spreading of slurry on land under unsuitable conditions increases the risk of pollution and nutrient enrichment of drainage water. These problems have been described and discussed by many workers e.g. McHugh (1973), Kelso (1973), Gracey (1974) and Watters and Thompson (1974).

From the early 1960s until the 1974/75 energy crisis large quantities of animal excreta in the form of slurry could be obtained simply for the cost of transport. It seemed possible that the application of these manures to nutrient deficient forest land might help solve the problems while at the same time providing nutrients required by the trees and might encourage more biological activity in infertile soils. To investigate the possible use of such organic manures two experiments were established in Lisnaskea Forest in 1967.

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Experimental Details

The aim was to determine whether pig and cow slurry applied at three different rates (in 1967) had any effect on the growth and the foliar nutrient concentrations of trees of different ages growing on two different soil types, as follows:

1. *Lisnaskea 5/67.* A Sitka spruce crop planted in 1953 on an oligotropohic peat. This crop was in a condition of serious "check" and was exhibiting all the symptoms associated with nitrogen deficiency — yellowness, slow growth and small needle size. It had received only a handful of basic slag (70 g/tree) at the time of planting in 1953.
2. *Lisnaskea 4/67.* A Sitka spruce crop planted in 1966, (the year before applying the experimental treatments), on an oligotrophic peaty gley (Savill and Dickson, 1975). This site had been fertilised with 250 kg rock phosphate (CRP)/ha broadcast in 1966.

Cow or pig slurry was applied to circular plots of 0.1 ha at rates of 1, 2 or 3 tanker loads, each of 3.2 m^3. The amounts of N, P and K applied in each treatment and equivalent amounts of conventional fertilisers are given in Table 1.

Table 1 Lisnaskea 4/67 and 5/67 — Treatments

		kg/ha element			Equivalent in kg/ha of:		
Treatment		N	P	K	Urea	CRP	KCl
Pig Slurry rate	1	131	20	64	285	136	128
	2	262	40	128	570	272	256
	3	393	60	192	856	408	384
Cow Slurry rate	1	83	29	56	181	204	112
	2	166	58	112	362	408	224
	3	249	87	168	543	612	336
Control		0	0	0	0	0	0

The experiments were laid out in unrestricted random designs with two plots of each treatment plus two untreated reference plots. With only seven residual degrees of freedom, the level of replication was normally too low to enable statistically significant treatment effects at the conventional 95 per cent probability level or more to be obtained. For this reason the actual probability levels for significance are shown in the final columns of Tables 2 and 3.

In terms of current Northern Ireland Forest Service recommendations for treatment of these sites (Anon, 1976), the quantity of nitrogen applied at the lowest rate was about the level considered suitable for checked Sitka spruce on oligotrophic peats though higher rates would not be regarded as harmful. Nitrogen is not considered necessary for young Sitka spruce on gleyed soils.

The recommended rate of phosphate application for P-deficient spruce on peat is 750 kg/ha rock phosphate. This was not achieved by any of the treatments though the highest rate of cow slurry approached it: on the gleyed site the recommended rate, 500 kg/ha rock phosphate, was exceeded only by this treatment.

Quantities of potassium supplied by both slurries were about the recommended levels for K-deficient sites (250 kg/ha KCl) at the middle rate of application. However neither site exhibited any visual symptoms of K deficiency in 1967.

Results

Effect of treatment on Growth and Foliar Nutrient Concentration on Oligotrophic Peat.

Table 2 shows the average annual growth of trees in Lisnaskea 5/67 for each treatment since 1967, mean heights at the end of 1974, growth 1967-74 and foliar N, P and K concentrations in 1976.

Table 2 — Lisnaskea 5/67 (Peat Site) — Annual Height Growth in cm, Total Growth 1967-74, Mean Heights in 1974 and N, P and K Concentrations (%DM) for Different Treatments

Experiment		Rate of applied pig slurry			Rate of applied cow slurry			Untreated plots	SE Treatment mean	probability level for significa-nce
		1	2	3	1	2	3			
Growth	1967	6	5	6	5	8	6	4	1.8 NS	30.5
	1968	27	17	20	11	21	24	2	3.7*	97.9
	1969	33	31	33	19	33	36	4	7.6 NS	85.2
	1970	30	41	47	16	32	39	12	6.1*	96.7
	1971	19	29	39	9	20	27	13	7.0 NS	83.5
	1972	22	27	40	12	23	25	16	8.3 NS	57.4
	1973	16	21	32	7	17	22	7	7.4 NS	67.1
	1974	17	19	34	9	14	18	9	7.2 NS	66.2
	1967-1974	170	189	250	88	169	197	66	45.2 NS	80.7
Mean height	1974	269	291	342	180	287	307	153	55.3 NS	70.5
Foliar N	1976	0.73	0.67	0.86	0.77	0.70	0.80	0.80	0.021**	99.6
P	1976	0.08	0.09	0.08	0.08	0.12	0.11	0.11	0.019NS	45.6
K	1976	0.62	0.74	0.65	0.81	0.92	0.83	0.86	0.068 NS	88.4

The year following slurry application, 1968, saw a marked improvement in the growth of the trees in all treated plots compared with that in the controls. In plots treated with the lowest rate of cow slurry there was a further slight improvement in 1969 but in the following the subsequent years, growth was about the same level as in the untreated plots.

Plots treated with the lowest rate of pig slurry (PI) and the middle rate of cow slurry (C2) responded in almost identical ways. Annual growth increased up to 1970 and thereafter there was a decreasing trend down to a rate which was marginally better than the controls in

1974. The middle rate of pig slurry (P2) and highest rate of cow slurry (C3) also produced similar responses though in these treatments the fall-off in the rate of growth from 1971 was not quite so marked. Only in the plots treated with the highest rate of pig slurry (P3) did growth remain at a reasonably satisfactory level throughout the entire period (1968-74), though in this case too there was a decreasing trend from 1971. This pattern of an initial increase in growth following the application of nutrients to checked plots, followed by a decline towards the pre-treatment level is similar to that obtained following the application of inorganic N and P fertilisers on oligotrophic peats in Northern Ireland (Dickson and Savill, 1974).

Total growth during the period 1967-74 increased with increasing rates of application of both types of slurry, though the plots treated with pig slurry did better with an average increase of 208 per cent compared with the untreated plots. Those treated with cow slurry had an average increase of 129 per cent.

The foliar levels of N, P and K shown in Table 2 were determined from samples of needles from one of the topmost whorls of branches of five randomly selected trees per treatment plot. Samples were collected early in June 1976. Though levels of N and K in the middle of the growing season are generally lower than in the dormant season, it is clear that N and P concentrations in all plots are very near or below the "critical" levels of 1.0 and 0.1% respectively quoted by Van Goor (1970), except in the plots treated with the 2 higher rates of cow slurry where P was adequate. K levels, by contrast were well above the "critical" 0.4 per cent.

Table 3 — Lisnaskea 4/67 (Gley Site) — Annual Height Growth in cm, Total Growth 1967-74, Mean Heights in 1974 and N, P and K Concentrations (%DM) for Different Treatments

Experiment		Rate of applied pig slurry			Rate of applied cow slurry			Untreated plots	SE Treatment mean	probability level for significa-nce
		1	2	3	1	2	3			
Growth	1967	22	18	17	21	17	19	16	1.0*	96.5
	1968	23	23	28	23	23	21	18	2.2 NS	78.8
	1969	35	38	36	36	33	35	31	2.1 NS	57.6
	1970	50	49	51	44	45	47	35	5.4 NS	49.2
	1971	39	45	49	36	40	46	28	6.2 NS	65.2
	1972	43	46	55	37	46	48	28	7.7 NS	62.2
	1973	34	69	46	26	39	39	21	15.3 NS	52.9
	1974	41	49	57	32	45	51	27	7.6 NS	79.2
	1967-1974	285	337	340	255	288	306	205	36.4 NS	74.3
Mean height	1974	309	362	366	281	313	328	230	36.3 NS	74.8
Foliar N	1976	0.83	1.00	0.99	0.92	0.84	0.92	0.92	0.047 NS	78.1
P	1976	0.06	0.09	0.09	0.06	0.07	0.09	0.07	0.010 NS	70.4
K	1976	0.52	0.47	0.52	0.56	0.40	0.48	0.50	0.084 NS	12.6

Effects of Treatment on Growth and Foliar Nutrient Concentrations on Oligotrophic Gley.

Table 3 shows the growth response in Lisnaskea 4/67, on the oligotrophic peaty gley site. Savill and Dickson (1975) have shown that nutritional deficiencies in this area of Northern Ireland are not as severe on gleys as on peats. Good growth can normally be promoted by applying rock phosphate at rates up to about 500 kg/ha.

Because this was a newly planted crop the pattern of response was rather different from the previous experiment; growth increased up to 1970 in the untreated plots and thereafter fell off slightly but maintained a reasonably steady level. Though growth in the treated plots was consistently better than in the controls it did not differ very much up to 1969.

From 1970 onwards growth in the treated plots was markedly better and within these it normally improved with increasing rates of applied slurry. It remained at a reasonably constant level in all plots from 1970: there was no indication of any fall-off with time as in Lisnaskea 5/67.

As in the previous experiment, among the treated plots, C1 gave the smallest response; responses to P1 and C2 were similar as were those to P2 and C3, though in both cases the pig slurry gave slightly better growth. Response to the P3 treatment was again the overall best. For any treatment, heights in this experiment were greater than those in the same treatment on the P53 oligotrophic peat site.

While foliar nitrogen levels in 1976 were generally just below the "critical" 1% level, if the seasonal depression in concentration is taken into account they were probably adequate to sustain reasonable growth in all plots except those treated with the lowest rate of pig slurry and middle rate of cow slurry, though it is possible that even these levels were also adequate. Foliar P levels appear surprisingly low in all plots. They do not normally fluctuate greatly during the year and the fact that P was just below 0.1% dry matter indicates that it might be limiting growth to some extent. Foliar K concentrations were adequate in all plots.

Discussion

These two experiments have shown that cow and pig slurry can improve the growth of Sitka spruce on oligotrophic peats and gleys in much the same way as can be done by the application of mineral fertilisers. The patterns of response were similar to those described by Dickson and Savill (1974) and Savill and Dickson (1975): on peat, growth improved for 3-4 years and then fell off again while on the gleyed site a more permanent improvement was achieved.

It is difficult to give a definite indication as to what constituents of the slurry were responsible for the improvements in growth but some inferences can be made. For a given volume, the pig slurry contained about 60% more N, 15% more K, and 30% less P than the cow slurry. On both sites there were better responses to pig slurry than to cow slurry so it seems possible that N was having a greater influence on growth than P. Linear correlation coefficients between growth (1967-74) on each site and the quantities of applied N, P and K were:

Lisnaskea 5/67 (Peat): N = 0.95*** P = 0.72* K = 0.92**
Lisnaskea 4/67 (Gley): N = 0.94*** P = 0.78* K = 0.90**

These correlations tend to confirm that there was a closer relationship between growth on both sites and the quantity of N applied in the slurry than there was between growth and P. The relationships between growth and K were also good though work already quoted by Dickson and Savill (1974) and Savill and Dickson (1975) on peats and gleys suggests that little real importance can be attached to them. Though it would be unwise to read too much into the results of these correlations they seem to be slightly at variance with results of work with inorganic fertilisers on these sites where applied phosphorous normally had the greatest influence on growth in crops of the kind being dealt with here.

Growth in the plots treated at the highest rate of applied pig slurry on the peat site in particular remained at a high level for much longer than would be expected if only mineral fertilisers had been applied. It could be that the very high rate of nitrogen, some of it in slowly available forms, supplied by this dressing was solely responsible for this effect. It is also possible that from this heavy dressing there was some additional effect, e.g. the promotion of more biological activity in the peat resulting in a reasonably satisfactory recycling of nutrients for a period of at least eight years. Whatever the cause, it merits more detailed investigation.

There are many points to be considered when deciding whether slurry could be applied to forests:

1. Slurry is bulky and therefore expensive to transport.
2. Distribution in forests is likely to be a major problem. Whereas farms tend to be relatively well roaded and most parts are accessible at least to small tractor-towed slurry tankers, forests, particularly the upland ones, most in need of applied nutrients, are not.
3. In order to apply slurry at the rates at which nutrients are required, enormous quantities would be needed. To give some indication of the magnitude, it would require approximately 28 cubic metres or 28 tonnes of slurry to apply 115 kg urea to one hectare. This is the amount contained in 250 kg urea which is currently the recommend application per hectare to checked

crops. Based on figures quoted by Gracey (1974) the annual dung and urine output of upwards of 2.7 cows would be needed to provide this quantity of slurry. A more daunting prospect is that of supplying the equivalent amount of P contained in 750 kg CRP (the amount recommended per hectare for oligotrophic peats at planting). This would require 163 tonnes of slurry. With the same weight of rock phosphate 217 ha could be treated.

4. One of the great potential values of slurry for forestry is the nitrogen it contains. Work described by Dickson and Savill (1974) indicates that this nutrient is rarely, if ever, deficient in Northern Ireland forest soils in the early years of a crop's life when application would be relatively easy. At the time when nitrogen is really needed on oligotrophic peat, crops have just closed canopy and are virtually impenetrable. The only practical way to apply nutrients is from the air. This could not conceivably be economic with a material of such low nutrient concentration as slurry since aerial application of conventional fertilisers is itself only marginally economic.
5. Many upland forests lie in water catchment areas where run-off following the application of slurry could present some degree of health risk and of nutrient enrichment of the drainage water. With the latter, the possibility of algal "blooms" in reservoirs and the subsequent deterioration of the water would be greatly increased.
6. Finally, the handling of slurry is always a dirty and above all smelly job. Coping with the very large quantities needed by forests might create labour problems.

Thus, while slurry can provide all the nutrient elements required to promote good tree growth its use in forestry is likely to be extremely limited because of high costs and other problems connected with transport and application. If it has a place at all, it is likely to be confined to small areas of forest such as shelter belts which are convenient to the source of the material and to a road. Since the steep rise in the costs of fertilisers in 1974-75, farmers have shown more interest in the value of animal manures as a source of nutrients for their crops. They are now learning to recycle efficiently what was formerly regarded as a troublesome waste product. Consequently little slurry is likely to be available for use in forestry.

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