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END OF PROJECT REPORT

PROJECT 4267

MINIMUM PHOSPHORUS NEEDS FOR SILAGE PRODUCTION

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SUMMARY

- Phosphorus recovery in product at the low stocking rates was poor, but improved in the high stocking rates. It is deduced that when the new Teagasc recommendations are implemented, recovery of applied P in product should be very efficient.
- Soil should be maintained at Index 2 (3.1 to 6.0 mg P l^{-1}) for optimum silage production
- Slurry should be recycled to the silage land early in the year or after 1st or 2nd cut silage.
- Maintenance fertilizer P should be used to supplement P in the slurry in order to replace removal in milk, meat and other losses
- Where slurry is recycled, maintenance fertilizer P for silage land will be less than for grazing land as concentrates are an important source of P input to the farm. The fertilizer P maintenance requirement will normally be between 0 and 10kg P ha^{-1} yr^{-1}.
- Where slurry is not recycled, maintenance P requirements for silage land are higher at 20 to 30 kg P ha^{-1} yr^{-1}
- Do not apply insurance P dressings to silage land. It will not increase production and may lead to increased potential for P loss to water.

INTRODUCTION

The aim of the experiment described here was to measure the minimum P requirement for grass under cutting conditions. It was carried out from 1987 to 1996 inclusive. The results of the first four years have been published as a Ph.D. thesis (Power, 1992) and the results of the individual years have been summarised in the *Annual Research Reports* of Teagasc, Johnstown Castle. Only the results for the final four years (1993-1996) are reported here.

METHODS

The experiment was conducted at three sites - Johnstown Castle, Clonroche in Wexford and Oak Park in Carlow. The experiment had ten treatments with five replications giving 50 plots of 10m by 4m at each site. The plots were reseeded with ryegrass in 1986, each plot received basal applications of nitrogen, sulphur and potassium each year. The ten treatments were a control, (0), 20, 30, 40 kg P ha^{-1} yr^{-1} applied in October or March, 50 kg P ha^{-1} yr^{-1} applied in March and 100 and 200 kg P ha^{-1} applied once only in October 1986. There were three cuts each year in May, July and October. The third harvest was not measured at Johnstown Castle in 1996. No slurry was applied to any of the plots. Soil samples were taken in October each year after the third cut but before the autumn P applications.

RESULTS AND DISCUSSION

The results of the total dry matter (DM) yields and soil test results for each of the four years are summarised in Table 1. There was a significantly lower DM yield from the control plots (*i.e.* received no P) than from at least one of the treatments that received P at Johnstown Castle and Clonroche in three of the four years. The difference was significant in two of the four years at Oak Park. There was no significant difference between the lowest P treatment (20 kg P ha^{-1}) and the higher P treatments. In many cases the lower P treatments gave higher yields than the highest P treatments but the differences were not significant. The difference in yield between the zero P plots and the highest yielding plots was generally about 1 t DM ha^{-1} yr^{-1} or about 10% of total yield. The biggest difference in yield was between years and sites. Over the four years Clonroche gave the most consistent and highest yields. Oak Park had the lowest (1995 - due to drought) and highest (1996) yields. The response to P appeared to be relatively independent of the average yield over the years and sites.

Yields with the high single initial P applications were not significantly higher than the zero P, except for the 100 kg treatment at Johnstown in 1993.

There was no significant difference between spring and autumn P application. However, there was a tendency for spring applications to give a marginally higher yield in the majority of cases.

The P content of the herbage showed a greater response to added P than DM yield.

Treatments had a greater influence on soil test P levels than on grass DM yield (Table 1). The zero P treatments had the lowest values at about 2 to 3 mg P l^{-1} soil or about half the values of the plots receiving the lowest P treatments. The average soil P levels at the start of the experiment, in 1986, was 5, 11 and 40 mg P l^{-1} soil for Clonroche, Johnstown Castle and Oak Park, respectively. The highest P treatments maintained the soil P at the first two sites over the 10 years but it approximately halved at the Oak Park site where the initial P was very high.

There was a significantly higher soil P test for the 40 kg P ha^{-1} treatment in spring compared to the same treatment in autumn at Johnstown Castle. This could be due to the shorter interval between application and sampling but may also be partly due to better retention of spring-applied P in the soil.

Table 1: The effects of chemical fertiliser P on grass dry matter yield and soil test P on the three sites for the last four years of the ten year experiment

kg P ha^{-1} yr^{-1}	0	March 20	March 30	March 40	October 20	October 30	October 40	October 50	1986 100	1986 200	mean	s.e.d
Total DM yields t ha^{-1}												
Clonroche												
1993	13.35	13.52	13.47	13.80	13.52	14.20	13.69	13.83	14.27	13.62	13.73	0.67
1994	12.16	13.19	12.39	13.55	12.56	12.90	12.88	12.68	11.91	13.07	12.73	0.62
1995	10.79	11.83	11.34	12.01	11.13	12.34	11.21	12.05	10.85	10.77	11.44	0.34
1996	12.21	13.52	12.92	13.43	13.43	13.30	13.14	12.95	12.80	12.50	13.03	0.68
Johnstown Castle												
1993	10.18	11.01	11.05	11.16	11.20	11.16	11.39	11.39	11.48	10.99	11.10	0.32
1994	8.83	9.63	8.80	9.77	9.56	9.36	9.31	9.79	9.09	9.58	9.37	0.52
1995	10.90	11.23	11.11	11.83	10.99	11.19	11.27	10.89	11.20	10.80	11.14	0.34
*1996	8.55	9.47	9.12	9.56	9.03	9.59	9.58	9.41	9.20	8.80	9.25	0.36
Oak Park												
1993	10.42	10.40	11.60	10.83	10.29	10.74	10.40	10.89	10.09	10.37	10.61	0.55
1994	11.21	11.59	10.98	11.21	11.02	11.33	11.49	11.03	11.42	11.27	11.26	0.47
1995	7.59	7.92	7.36	7.10	7.20	7.75	8.32	7.94	7.16	7.26	7.56	0.53
1996	13.48	14.02	14.19	14.30	13.62	14.28	14.47	14.89	13.40	13.10	13.97	0.63
Soil test P, mg P l^{-1}												
Clonroche												
1993	1.7	2.6	3.1	3.6	2.6	3.5	4.0	4.2	2.2	2.9	3.0	0.26
1994	2.1	3.4	4.3	4.9	4.2	4.2	4.7	5.7	2.5	3.3	3.9	0.37
1995	1.7	2.6	3.3	4.2	2.9	3.5	4.3	4.6	1.8	2.3	3.1	0.29
1996	2.0	3.4	3.8	5.2	3.1	5.1	5.6	5.8	1.9	2.9	3.9	0.51
Johnstown Castle												
1993	3.1	6.1	6.6	9.7	5.9	5.6	7.3	8.6	6.6	6.2	6.6	1.45
1994	3.1	6.5	8.2	11.0	6.4	6.5	8.0	9.4	6.0	5.7	7.1	1.33
1995	2.2	6.0	7.0	11.2	5.1	5.2	7.3	8.6	3.8	3.9	6.0	1.17
1996	2.5	5.3	7	11.3	5.8	6.3	8.5	10.6	4.1	4.2	6.6	1.00
Oak Park												
1993	3.2	6.4	15.1	24.3	10.4	19.3	17.2	17.4	6.6	7.6	12.8	6.00
1994	4.0	6.7	16.3	26.0	11.7	22.4	17.2	17.2	6.6	7.5	13.6	5.90
1995	3.1	7.4	20.1	29.8	12.5	22.1	23.1	20.3	6.7	7.7	15.3	6.35
1996	4.1	8.3	16.6	24.0	13.5	20.1	20.7	16.7	5.1	4.9	13.4	6.10

* The third harvest was not measured at Johnstown Castle in 1996.

There was a poor correlation between soil test P and DM yield. This is not surprising in view of the relatively small influence of P treatments on DM yield and the relatively large influence on soil test. It appears

that the major influence of soil test P on yield is at levels lower than those found at the zero P treatments in this experiment, namely between 0 and 2 mg P l^{-1}. For the conditions of this experiment over 90% of maximum yield can be obtained at the upper end of soil Index 1 (0 to 3 mg P l^{-1}).

PHOSPHORUS RECOMMENDATIONS FOR SILAGE

The Teagasc P recommendations for silage are based on achieving/maintaining soil test P levels which will ensure full crop yields and applying a P dressing to replace the P removed by the crop. The result of the experiment described above and a review of other P response experiments carried out on grassland in Ireland over the past 30 years showed that full grass production under cutting conditions, can be obtained at Morgan soil test P levels between 4 and 6 mg P l^{-1} (Soil Index 2), provided maintenance P dressings are applied.

Target yields for first and second cut silage are 6 and 4 t DM ha^{-1}, respectively. The P removals for these crops, assuming 0.3% P in the herbage DM, were calculated for a soil at Index 2 (3.1 - 6.0 mg P l^{-1}) (Table 2).

Table 2: Grass yields and P removal in first and second cut silage at 0.3% P in the herbage (Index 2).

Silage	Grass Yield (t DM ha^{-1})	P removal (kg ha^{-1}) at 0.3% P in herbage DM
First Cut	6	18
Second Cut	4	12
Total	**10**	**30**

Therefore, for a one cut silage system 18 kg P ha^{-1} are required to replace the P removal (maintenance) and 30 kg P ha^{-1} are required for a two cut system, where slurry is not recycled.

CALCULATING MAINTENANCE FOR SILAGE LAND

It is recommended that slurry, from animals fed on silage, should be recycled, in proportion to silage yields, to the land where the silage was cut. The recycled slurry will satisfy most of the P requirements of silage land because the animals that eat the silage and concentrates remove only about 30%, or less, of the P present. Therefore, an annual application of 5.4 and 9 kg ha^{-1} of fertilizer P should be adequate for a one and two cut silage system, respectively, as the annual maintenance dressing for soils at Index 2. This does not include P removed in aftermath grazing.

Another approach to this calculation is to assume that the stocking rate on the farm is 2.5 livestock units (LU) per hectare. Each LU excretes 13 kg P yr^{-1} 1 or 5.5 kg P during the five month winter feeding period. Therefore, there would be 27.5 kg P ha^{-1} (5.5 x 2.5 x 2) available for recycling in the slurry to the silage area. The balance of 2.5 kg P ha^{-1} yr^{-1} would be needed as a fertilizer maintenance dressing for a two cut silage system (at the 0.3% P level in Table 2).

In the situation where slurry is not recycled, the full P removal in the crop will have to be replaced in order to maintain soil P fertility. In general, this is not considered sustainable (economically or environmentally) and the slurry should be recycled to the silage area. However, as a solution where there is no practical alternative, for example on an out-farm, the full amount of P removed in the crop should be replaced by chemical fertilizer.

CONCENTRATE FEED AND P BALANCE FOR SILAGE AND CUTTING AREA

Significant quantities of P are imported onto farms in concentrate feed. Therefore, as levels of concentrate feed increase the requirement for chemical fertilizer P to maintain a P balance on the farm decreases.

The following example (Figure 1) is used to illustrate the P balance on an intensive 20 ha dairy farm, with 2.5 LU ha^{-1} (50 cows), 0.5 t concentrates (0.5% P) fed cow^{-1}, a yield of 5000 l milk cow^{-1} and one calf per cow.

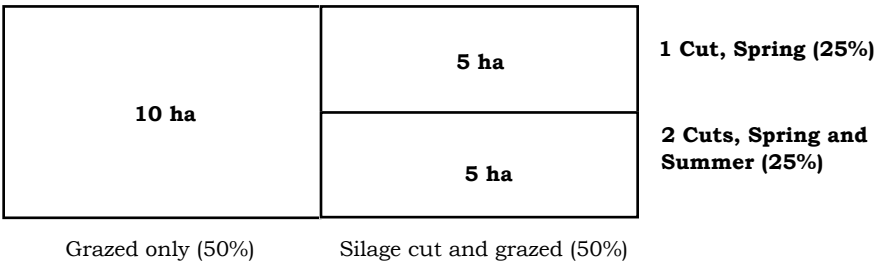

Figure 1: Schematic representation of silage and grazing areas on a 20 ha intensive dairy farm.

The total output of P from this farm is 270 kg yr^{-1} which it is made up of 250 kg P in the milk and 20 kg P in the calves. The total P input in concentrates is 125 kg P. The farm P balance, therefore, is a net removal of 145 kg. This is equivalent to 13.5, 6.25 and 7.25 kg P ha^{-1} for outputs, input and balance (removal), respectively, on a whole farm basis (Table 3).

Table 3: Calculation of P outputs, inputs and removals (kg/ha^{-1}) for silage, grazing areas and whole farm, on a 20 ha dairy farm with 50 cows producing 5,000 l milk and fed 0.5 t concentrates cow^{-1} year^{-1}

	Silage and Aftermath	Grazing Area	Whole Farm
	10ha	**10ha**	**20ha**
Outputs			
Milk	9.6	15.4	12.5
Calves	2.0	0	1.0
Total	**11.6**	**15.4**	**13.5**
Inputs			
Concentrates	10.0	2.5	6.25
Removals	**1.6**	**12.9**	**7.25**

The contribution that the level of concentrate feeding has on the overall farm P balance is very evident. For example, the removal, on a whole farm basis would be reduced from 7.25 to 1 kg (7.25-6.25 kg) P ha^{-1} if the concentrate input were doubled i.e. increased from 0.5 to 1 t cow^{-1} yr^{-1}.

On a REPS type dairy farm (40 cows producing 5000 l and one calf cow^{-1} yr^{-1} on 20 ha with a concentrate input of 0.25 t cow^{-1} and 1 cut of silage) the P balance for the grazing and silage areas calculated in the same way was removals of 11 and 5 kg ha^{-1}, respectively.

P balance for silage areas: To determine P fertilizer recommendations based on matching P inputs with removals it is necessary to establish a P balance for silage areas. The overall P balance for the silage area is shown in Table 3. The production from the first and second cut silage aftermaths must be calculated separately to derive a total P balance for each area. It is estimated that approximately 77%, 15% and 8% of the milk produced during grazing comes from the grazing only area and the aftermath from the first and second cut silage areas, respectively. The concentrate P inputs fed at grazing are generally recycled to the grazing only area. Therefore, the total P removals in milk during

grazing for the grazing only area, the first and second cut silage aftermaths amount to 154, 30 and 16 kg P, respectively. This is equivalent to 15.4, 6.0 and 3.2 kg P ha^{-1}, respectively, for the three areas. An adjustment is required for the grazing only area balance to allow for the concentrate P inputs of 25 kg. The resulting net balance (removal) for this area is 129 kg or 12.9 kg P ha^{-1}.

The average net P removals for the grazing aftermaths from the two silage areas are 46 kg P or 4.6 kg ha^{-1} (based on outputs of 30 and 16 kg P, or 6.0 and 3.2 kg P ha^{-1}, removals during grazing of the two silage areas). Therefore, the net average P removal from the silage area is 16 kg or 1.6 kg ha^{-1}. This balance depends on the slurry being recycled in proportion to the DM yield from the two silage areas, namely, 40% of the slurry returned to the one cut only silage area and 60% to the area cut twice for silage. Alternatively, the slurry can be applied uniformly to the entire silage area every year, alternating the area used for second cut.

P BALANCE ON A BEEF FARM

A similar situation exists on intensive beef farms in relation to farm P balances. This is illustrated in the following example. The P balance for a 20 ha intensive beef farm stocked at 2.5 LU ha^{-1} with a concentrate input of 0.5t LU^{-1} and an output of 1000 kg live weight ha^{-1} yr^{-1} is shown in Table 4. Half the farm is cut for first cut silage and

Table 4: The P balance for an intensive 20 ha beef farm with 50 LU producing 20,000 kg live weight gain yr^{-1} and a concentrate input of 25 t yr^{-1} (0.5 t LU^{-1})

	Farm kg P, 20 ha	**kg P ha^{-1}**
P Outputs		
Live weight gain 20,000 kg @ 8 g P kg^{-1}	160	8.0
P Inputs		
Concentrates 25t @ 5 kg P t^{-1}	125	6.25
Removals	**35**	**1.75**

25% for second cut.

The P balance for the farm is a deficit, or removal, of 35 kg (1.75 kg ha^{-1}) which is only 25% of that for the dairy farm shown in Table 3. The P balance was calculated for the silage areas in the same way as for the dairy farm. The assumption is that 60% and 40% of the live weight gain (LWG) is produced during grazing and winter feeding periods, respectively. The concentrates fed at grass (20% of total) were fed to the animals on the grazing area only. The P removals in LWG are 74, 15 and 7 kg P during grazing from the grazing only area, first cut silage aftermath and second cut silage aftermath, respectively.

The P balance is a surplus of 14 kg (1.4 kg ha^{-1}) for the silage area. This compares with a deficit of 17 kg P ha^{-1} (1.7 kg ha^{-1}) for the intensive dairy farm given above. The higher P removal, in milk, from the dairy compared with the beef farm is responsible for the difference. If no concentrates are fed, 7.4 and 8.6 kg P ha^{-1} will be removed from the grazing and silage areas, respectively.

P RECOMMENDATIONS FOR SILAGE LAND

In the P recommendations for silage in Tables 5 and 6, Soil Index 2 (3.1 - 6.0 mg P l^{-1}) is considered adequate for grass cutting and subsequent grazing. At high stocking rates 2.0 LU ha^{-1} and greater, for early grass in silage areas a soil P level of Index 3 (6.1-10 mg P l^{-1}) is recommended. To ensure optimum silage yields over a range of soil types the P level should ideally be at or above the mid point of Index 2. Therefore, an additional increment of 5 kg P ha^{-1} may be used for Index 2 when the soil P level is between 3.1 and 4 mg l^{-1}. The chemical P fertilizer recommendation for silage land where all slurry is recycled are shown in Table 5. Additional P will be required where no concentrates are fed and less P will be required where more than 0.5 t LU^{-1} is fed.

Table 5: Fertilizer P recommendations (kg P ha^{-1}) for silage swards where 0.5 t* concentrates are fed and slurry is recycled.

Soil P Index	a) Spring Silage (1 cut)	b) Spring & Summer (2 cuts)	c) Summer Silage (1 cut)
1	20	20	25
2	10	10	15
3	0	0	0
4	0	0	0

* Reduce these recommendations by 2 kg ha^{-1} for every 0.1 t LU^{-1} yr^{-1} increase above 0.5 t LU^{-1} yr^{-1} of concentrates fed. Equally, increase by 2 kg ha^{-1} for each 0.1 t decrease below 0.5 t.

The fertilizer P for silage land where slurry is not recycled is shown in Table 6.

Table 6: Fertilizer P recommendations (kg P ha^{-1}) for silage swards where slurry is not recycled.

Soil P Index	a) Spring Silage (1 cut)	b) Spring & Summer (2 cuts)	c) Summer Silage (1 cut)
1	40	50	35
2	30	40	25
3	8	10	7
4	0	0	0

To allow for variation in soils and soil test results, an insurance factor of 30% more than removals is included in the final recommendations at Index 2 shown in Table 6. For the same reason a small P fertilizer input, of the same order, is also recommended at Index 3 where slurry is not recycled (Table 6). The recommendations are rounded off in Tables 5 and 6. The recommendation shown in Table 5 is for an intensive dairy farm. Lower levels of P will be adequate on beef farms and extensive dairy farms.

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