Teagasc
The Science of Farming and Food

END OF PROJECT REPORT

PROJECT 4510

THE EVALUATION OF PHOSPHORUS SOURCES FOR NUTRIENT BUDGETING ON ORGANIC FARMS

Johnstown Castle,
Research Centre,
Wexford.
Tel/Fax: 053-42888/42004

Rural Environmental Series No.16

THE EVALUATION OF PHOSPHORUS SOURCES FOR NUTRIENT BUDGETING ON ORGANIC FARMS

END OF PROJECT REPORT

ARMIS 4510

Authors

F.S. MacNaeidhe and A.N. O'Sullivan

Johnstown Castle Research Centre
Wexford

February 1999

ISBN 1 84170 31 9

Teagasc acknowledge with gratitude the support of European Union (AIR3-CT920051) in financing this research project.

Agriculture and Food Development Authority

The Science of Farming and Food

EUROPEAN UNION

Teagasc, 19 Sandymount Avenue, Ballsbridge, Dublin 4

TABLE OF CONTENTS

SUMMARY

The use of synthetic P fertilisers such as superphosphate is not permitted by regulation on organic farms. The use of basic slag and rock phosphate is permitted by regulation but the effects of the application of these compounds on the soil and herbage concentrations of phosphorus (P) on organic farms has not been assessed. Experiments were carried out from 1994 to 1997 on the effect of basic slag and rock phosphate on the concentrations of P in four different soil types and on herbage in organic grassland. Superphosphate was included in some of the experiments as a comparison. The investigations showed that:

i. Superphosphate applied at equivalent rates of elemental P gave the largest initial increase in soil and herbage concentrations of P but was no more effective at raising the soil and herbage concentrations of this element than basic slag or rock phosphate in the long term.

ii. The application of basic slag and rock phosphate gave increases in soil and herbage concentrations of P which were comparable to those obtained with superphosphate but were more slow acting

iii. Basic slag gave an increase in the concentration of P in an organic soil which was high in P (> 10 mg/kg) but gave only a slight increase of P in the herbage.

iv. Basic slag gave an increase in soil P concentration in a range of soils and was more persistent in these soils than superphosphate.

v. Basic slag gave an increase in herbage yield which was equivalent to that given by superphosphate in a low P soil.

vi. Rock phosphate gave a larger herbage yield increase in a low P soil than superphosphate or basic slag.

vii. Rock phosphate is a more persistent source of P in low P soils than superphosphate or basic slag.

viii. In soils with a high pH rock phosphate may be less effective as a phosphatic fertilizer than superphosphate or basic slag.

CONCLUSIONS

The following conclusions were made on a result of the field experiments and pot experiments carried out with basic slag, rock phosphate and superphosphate.

❶ Basic slag and rock phosphate compare favourably as sources of P with superphosphate and can be used on organic farms to increase the soil P concentration when this is low and the deficiency affects grass and crop yields. Basic slag and rock phosphate can also be used on conventional farms on a substitute for superphosphate. The above results are in agreement with those of Mattingly (1968), Mattingly and Penny (1968), Hodges et al (1968), Gerritson (1967) and Fassbender and Muller (1969). These investigations showed that basic slag and to a lesser extent, rock phosphate were as effective on a range of crops as was superphosphate. The use of basic slag as a substitute for superphosphate involves the recycling of industrial waste or biproduct and contributes to world energy conservation. It can therefore be considered to be an environmentally beneficial practice.

❷.In an organic soil which is high in P (> 10 mg/kg) the application of basic slag in a grass/clover sward at 100 kg and 200 kg/ha equivalent to 7.0 kg and 14.0 kg available elemental P increases the soil P concentration but does not increase the P concentration of the herbage. In an organic soil which is low in P (2.3 - 3.5 mg/kg) the application of basic slag, rock phosphate and superphosphate at elemental P rates similar to above gives an increase in the soil and plant concentrations of P. Hodges et al (1968) achieved similar results with these three fertilisers on a fine sandy soil which was low in P in Florida.

❸ The soil concentrations of P are increased to a greater extent by the application of superphosphate than by the application of basic slag and rock phosphate at equivalent rates at first. With the progression of time the P concentration of soil treated with superphosphate decreases at a more rapid rate compared with soils treated with basic slag and rock phosphate. This shows that basic slag and rock phosphate have a greater residual effect than superphosphate. This greater residual effect is due to the slower rate of release of the P from the basic slag and the rock phosphate. Hodges et al (1968) found that residual levels of P were higher in the soil following the application of basic slag and rock phosphate but that superphosphate gave equivalent production of beef on grassland compared to these two fertilisers when applied at equivalent rates.

4 Rock phosphate applied at 7.0 kg and 14.0 kg P per hectare gave an increase in the percentage dry matter in the herbage of a grass/clover sward but did not give an increase in the dry matter yield when the herbage was yielded after seven weeks of growth. Neither the basic slag or the superphosphate gave an increase in yield or the dry matter content during that period. Rock phosphate gave an increase in the dry matter yield of herbage when the second harvest was taken from growth made over July and August. Superphosphate at equivalent rates gave the lowest herbage dry matter yield. The increased yield following the application of the rock phosphate was due to the larger residual effect of this fertiliser. Several investigations which were carried out three decades ago comparing rock phosphate and basic slag with superphosphate have given similar results. Hodges et al (1968) showed the residual P was found in a sandy soil 11 years after the application of rock phosphate and beef production increased by up to 59 percent following treatment with basic slag and rock phosphate. Mattingly and Penny (1968) found that grass grew less well and took up less P when treated with rock phosphate and basic slag compared with superphosphate during the first 12 weeks of growth but that over the whole season more P was taken up by rock phosphate and basic slag. Smith (1968) also found that basic slag had good residual effect in the soil but rock phosphate did not compare favourably with other phosphatic fertilisers.

5 The effectiveness on otherwise of rock phosphate and basic slag as sources of P in comparison with superphosphate is dependent largely on the pH of the soil. The pH of the soil at the experimental site where a good response to rock phosphate was obtained was 6.3. Investigations with phosphatic fertilisers carried out elsewhere show that

superphosphate gives a better response in soils with a high pH and basic slag and rock phosphate gives better results in acid soils. Ofori (1968) showed that basic slag gave better results than superphosphate in acid clayey soils but was less effective in alkaline soils. Devine et al (1968) showed that while superphosphate gave good results with oats and barley in a sandy soil with a pH of 7.1 basic slag was much less effective and rock phosphate was inert. These two latter fertilisers were much more effective in the more acid soils (pH 4.7 to 6.5). On the other hand Stahlin (1968) found that superphosphate depressed grass yields in acid soils. A review of the literature shows that superphosphate is most effective within a soil pH range of 6.8 to 8.0. Basic slag is most effective within a range of 5.5 to 6.8 and rock phosphate is most effective at pH values below 6.5.There has been a reduction in the use of lime in agriculture in the past decade with an accompanying fall in the overall soil pH. Under these circumstances basic slag and rock phosphate will be more useful as phosphatic fertilisers than heretofore.

6 It was expected that some leaching of P would occur following the application of the three fertilisers especially in the more light textured soils. In the pot experiment the soil P was measured at the 0-5 cm and 5-10 cm levels in the pots for this reason. This investigation showed that little or no movement of P occurred between these two levels over a period of 200 days in the case of superphosphate or basic slag. Soil texture had no effect on leaching and there was no evidence of any greater P movement in the Screen loamy sand compared with the Rathangan clay loam. Investigations by Mattingly (1966) and Bolton and Coulter (1966) suggest that the reduction in soil P over time may be due at least in part to leaching of the P particularly in light textured soils. Mattingly found that in light sandy soil only 7 per cent of the P from superphosphate was retained in the surface A horizon but 41 percent of the P from basic slag and 67 percent of the P from rock phosphate was retained in the A horizon. Bolton and Coulter (1966) found similar results in a light textured forest soil. Most of the P which was leached from the A horizon was retained in the B horizon and large scale leaching into water courses with the accompanying risk of environmental pollution did not

occur. The evidence from the Johnstown trials show that the decrease over time in the soil P concentration is due to adsorption of the P on the clay fraction. Leaching, even in the case of the Screen loamy sand is minimal and the risk of environmental pollution is small. On the other hand application of superphosphate in soils with a higher pH could result in leaching of P especially at higher rates of application. Such a risk does not occur with basic slag and rock phosphate which release lower amounts of P at high soil pH values.

7 The source of basic slag has an influence on the trace element and heavy metal content of this fertiliser. Before basic slag is recommended for application on an organic farm the source of the slag should be checked and an analysis of the slag should be carried out to assess the concentrations of trace elements and heavy metals. Analysis of basic slag from different sources was carried out at Johnstown twenty years ago. This showed that high concentrations of heavy metals were present in some samples from eastern Europe. The elements present in addition to P were magnesium, manganese, fluorine, aluminium, iron, copper, cobalt, boron, chromium, vanadium and titanium. Farrer (1968) found that none of the trace elements or heavy metals in a similar slag had any affect on plant growth. Routine application of basic slag containing heavy metals could result in the build up of such toxins in soil over time. This in unlikely to occur in organic soils where occasional dressing are made but is more likely to occur in conventional soils where routine fertiliser applications are the normal practice.

INTRODUCTION

Organic agriculture has been expanding steadily in Ireland over the past decade. In 1994 the area under organic farming was 5500 hectares. In 1977 this had increased to 18,309 hectares (Gibney 1997). A survey of organic farms which was carried out in 1992 showed that many of these farms are set up on land which is low in phosphorus (P) (MacNaeidhe 1992). The organic standards do not permit the use of synthetic P fertilisers on organic farms but the use of basic slag and rock phosphate is permitted when the soil concentrations of P is low (Anon 1991). Before this investigation was carried out there was no information on the effect of application of these two materials on the soil and herbage concentrations of P. The purpose of this investigation was to assess the effects of basic slag and rock phosphate applied at different rates on the soil and herbage concentrations of P in organic soils. Experiments were carried out in the field and under glass from 1994 to 1997 on the effects of basic slag and rock phosphate on the concentration of P in different soil types and in herbage. Many investigations have been carried out with superphosphate over the past several decades and for this reason superphosphate was included in some of the experiments as a standard treatment.

METHODS

Two field trials and a pot experiment were carried out. The field experiments were carried out at the Johnstown Castle Organic Experimental Farm. In the field experiments the effect of application of various sources of P on soil and herbage concentrations and on residual P were assessed. At both sites the soil type was a well drained brown earth with a loam texture. The site of the first field experiment was used as a bull pen and the soil concentration of P was high (>10 mg/kg) due to the deposition of high amounts of dung. The site of the second experiment was selected due to the low soil concentration of P. A crop of hay was removed from the area before the experiment was laid out and farmyard manure was not applied to the area to replace the offtakes of P by the hay.

Field Experiment 1

This experiment was carried out in 1994 and 1995. Two rates of basic slag, 100 kg/ha (7 kg P/ha) and 200 kg/ha (14 kg P/ha) were applied in field plots 4m x 16m in area. The experimental design was a randomised block experiment with four replications. Twenty soil cores were removed to a depth of 10cm from each plot before the treatments were applied and at intervals of 42, 74, 110 and 399 days after treatment applications. An analysis of available soil P was carried out on each set of samples using Morgan's extracting solution (Byrne 1979). Herbage samples were taken in five 30cm x 30cm quadrates thrown at random in the 2.0m central strip of each plot before treatment application and at 41 days, 219 days, 332 days and 406 days after treatment application. The concentrations of P in the herbage were determined by colorimeter following digestion with sulphuric acid.

Field Experiment 2

The second field experiment was installed in 1996 and continued in 1997. Different rates of P were applied using three sources of P. The three sources of P were basic slag, rock phosphate and superphosphate. Basic slag and superphosphate were applied at three rates of P, i.e. 7.0 kg/ha, 14.0 kg/ha and 28.0 kg/ha. Rock phosphate was applied at 7.0 kg/ha and 14.0 kg/ha. The treatments were applied in 5m x 5m plots with a 1.0m discard. The experimental design was a completely randomised plot experiment with five replications. The soil and herbage in each plot was sampled and analysed for P before and after treatment. The site was mown and all herbage removed on May 10th. The fertilisers were applied on May 15th. The herbage was yielded in eight 30cm x 30cm quadrates thrown at random in each plot on July 1st. On August 28th the entire plot was yielded using a Haldrop plot mower. The dry matter yields of grass and clover and the P concentrations in the soil and herbage of each plot were measured. The pH of the soil at this experimental site was 6.2.

Experiment 3 - Pots

In 1994 and 1995 the effect of application of basic slag and superphosphate on the P concentrations in four soil types was evaluated in pots in the glasshouse.

In the pot experiment two sources of P, basic slag (7% P) and superphosphate (16% P) were applied in four soil types. The soils were air dried for one week in a glasshouse and passed through an 8mm diameter sieve to remove stones and other course material. Cylindrical plastic pots of 20cm diameter were filled to 2.5cm of the rim with each soil type. The quantity of soil in each pot was 5.0 l. The soils were brought to field capacity by the overhead application of distilled water until water percolating on to the saucer remained at a constant level of 0.5cm from the saucer rim for a period of 10 minutes. The pots were then lifted from the saucers and placed on gauze stands until all percolation onto absorbent paper placed underneath had ceased for 5 minutes. Each pot was then weighed and the fertilizer treatments were applied. Following application a saucer was placed underneath and over the surface of the pot to reduce moisture loss to a minimum. Field capacity was restored at four day intervals by adding the weight of water lost over the four day period to the saucer underneath. The basic slag and superphosphate fertilisers were applied to the pot surface in 10g of dried silica sand. The superphosphate granules were ground to a fine powder using a mortar and pestle for uniform dispersal with the sand. The basic slag was applied at 0.32g per pot and the superphosphate was applied at 0.14g per pot. These rates of application were equivalent to 7.0 kg P/ha. The four soil types which were used were clay loam (Rathangan series), loam (Johnstown series), loam (Clonroche series) and loamy sand (Screen series) (Gardiner and Ryan 1964).

The soil from the Clonroche series had a higher percentage of sand (45.6%) and was more free draining than the soil from the Johnstown series (34.9%). The latter soil was described as imperfectly drained (MacNaeidhe et al, 1996). The soils were sampled at intervals of 25, 50, 75, 100, 150 and 200 days and the available soil P concentrations were assessed at depths of 0-5 cm and 5 - 10 cm within each pot.

Five 1.0 x 5cm soil cores were removed from each pot for analysis. A factorial experimental design was used to assess the effect of basic slag application on soil P concentrations in four soil types at two depths. The interactions between concentrations at different depths in different soils and the interactions between the different sources of P at different depths in different soils were also assessed. Standard analysis of variance methods were used to determine differences between different treatment means at 0.5% and 0.1% probability levels (Le Clerg et al 1996). The P concentrations in the basic slag, rock phosphate and superphosphate were 7.02 per cent, 14.5 per cent and 16.0% respectively. The extractable P concentration of the basic slag was determined by extraction in 2 per cent citric acid. The P concentration of rock phosphate was determined by the formic acid method and that of the superphosphate was determined by the quinoline molybdate method (Byrne 1979).

RESULTS AND DISCUSSION

Field Experiment 1

The first field experiment was carried out on a soil which was high in P (Table 1). The experimental site was used as an exercise area for a bull and the concentration of P from the dung had build up over a period of several years. Application of basic slag at 7.0 kg/ha and 14.0 kg/ha gave an increase of 1.5 mg/kg and 2.7 mg/kg respectively in the soil concentrations of available P 42 days after application. The soil concentrations decreased thereafter but a slight increase was recorded after 399 days. This increase may have been due to an increase in soil moisture which occurred following rain in September 1995. The increased soil moisture has the effect of making P more soluble in the soil and this accounts for the higher P concentrations. The application of the basic slag also gave an increase in the herbage concentrations of P but this increase was small (Table 2). Such a small increase was expected due to the high soil concentration of P. The P levels in the herbage at from 0.518 to 0.628 mg/kg were high.

Table1: The effect of application of basic slag on the soil concentration of available P

Treatment	P applied kg/ha	Soil P concentration (mg/kg)				
		Before Application	Days after application			
			42	74	110	399
No treatment	-	10.3	10.3	10.0	10.3	10.5
Basic slag 100 kg/ha	7.0	10.3	11.8	10.0	10.3	11.3
Basic slag 200 kg/ha	14.0	10.3	13.0	11.0	10.5	11.3
S.E. (df=6)		1.000	0.382	0.553	0.276	0.640

S.E.= Standard Error
df = degrees of freedom

Table 2: The effect of application of basic slag on the concentrations of P in herbage							
Treatment	**P applied kg/ha**	**Soil P concentration (mg/kg)**					
		Before Application	**Days after application**				
			41	219	332	406
No treatment	-	0.601	0.603	0.605	0.518	0.603
Basic slag 100 kg/ha	7.0	0.603	0.618	0.623	0.560	0.605
Basic slag 200 kg/ha	14.0	0.595	0.605	0.628	0.575	0.595
S.E. (df=6)		0.0079	0.0082	0.0025	0.0084	0.0089

Field Experiment 2

The second field experiment was carried out at a site which had low concentrations of available P (Morgan's extract). The average available P at the site was 2.74 mg/kg. The effect of the three P sources on herbage fresh weight, dry matter and percent dry matter from the time of application on May 15th until the first harvest on July 1st is shown in Table 3. The effect of the different treatment on the total herbage fresh weight was small. Superphosphate at 7.0 kg of elemental P and rock phosphate at 28.0 kg of elemental P gave the largest dry matter yield. The dry matter yield was progressively reduced with increasing rates of application of superphosphate. Increasing rates of application of basic slag gave increased dry matter yields. There was little difference in the dry matter yield achieved with the two rates of rock phosphate which were applied. The application of rock phosphate gave an increase in the percentage dry matter of the herbage.

Table 3: The effect of three sources of P on herbage yields (g/m^2) first harvest, 1/7/96.				
Treatment	**P applied kg/ha**	**Total Herbage Fresh Weight (g/m^2)**	**Total Herbage Dry matter (g/m^2)**	**Per Cent Dry matter**
No treatment	-	1083.5	242.1	22.40
Basic slag 100 kg/ha	7	1160.0	250.8	21.64
Basic slag 200 kg/ha	14	1268.6	276.5	21.50
Basic slag 400 kg/ha	28	1244.9	293.8	23.70
Rock Phosphate 48.4kg/ha	7	1140.5	281.9	24.58
Rock Phosphate 96.8kg/ha	14	1042.7	285.1	25.90
Superphosphate 43.6kg/ha	7	1281.5	293.7	22.58
Superphosphate 87.2kg/ha	14	1313.8	279.7	21.62
Superphosphate 174.4kg/ha	28	1295.5	242.1	23.00
S.E. (df=36)		109.3	23.82	0.853

The sward at the experimental site had a clover content of 23.2 percent (dry matter basis). In order to assess the effect of the different sources of P on grass and clover herbage, the grass and clover in each sample from each treatment were separated and the dry matter was assessed. The distribution of the clover within the experimental area was not uniform but occurred in patches with a dense clover stand and in other patches which had fewer clover plants. For this reason it was not possible to detect any affects of the rates of P or the different P sources on the clover yield. For similar reasons the dry matter yields of grass although not as severely affected were also variable. The percentage dry matter in the grass was higher in the plots treated with rock phosphate than in those treated with basic slag or superphosphate. An increase in the percentage dry matter of the clover was also recorded.

Table 4: The effect of three sources of P on grass and clover yields (g/m^2) first harvest, 1/7/96.					
Treatment	**P applied kg/ha**	**Dry matter (g/m^2)**		**% Dry matter**	
		grass	**clover**	**grass**	**clover**
No treatment	-	189.4	52.7	23.9	16.2
Basic slag 100 kg/ha	7	167.9	82.9	24.0	17.5
Basic slag 200 kg/ha	14	205.5	71.0	23.4	17.6
Basic slag 400 kg/ha	28	202.3	91.5	25.0	20.2
Rock Phosphate 48.4kg/ha	7	201.2	80.7	27.1	20.1
Rock Phosphate 96.8kg/ha	14	233.5	51.6	28.3	22.2
Superphosphate 43.6kg/ha	7	228.1	65.6	24.1	17.2
Superphosphate 87.2kg/ha	14	195.8	83.9	23.5	19.3
Superphosphate 174.4kg/ha	28	208.7	89.3	25.0	19.4
S.E. (df=36)		23.0	20.5	0.83	1.28

The second harvest was taken after a period of 58 days of growth (Table 5). Several of the treatments gave an increase in the total herbage fresh weight, total herbage dry matter and the percentage dry matter in the herbage.

Table 5: The effect of three sources of P on herbage yields (g/m^2) second harvest, 28/8/96.				
Treatment	**P applied kg/ha**	**Total Herbage Fresh weight (g/m^2)**	**Total Herbage Dry matter (g/m^2)**	**Per cent Dry matter**
No treatment	-	844.6	189.4	22.5
Basic slag 100 kg/ha	7	884.8	193.7	21.9
Basic slag 200 kg/ha	14	1080.0	227.2	21.1
Basic slag 400 kg/ha	28	1019.8	233.8	22.9
Rock Phosphate 48.4kg/ha	7	1013.8	251.8	24.6
Rock Phosphate 96.8kg/ha	14	1022.4	272.5	26.4
Superphosphate 43.6kg/ha	7	917.0	200.2	21.8
Superphosphate 87.2kg/ha	14	928.8	201.2	21.5
Superphosphate 174.4kg/ha	28	1039.8	230.1	22.1
S.E. (df=36)		59.34	14.47	0.6745

Basic slag at 200 kg/ha and superphosphate at 174.4 kg/ha gave the largest fresh weight yields. Rock phosphate at 48.4 kg/ha and 96.8 kg/ha gave the largest dry matter yields and the largest dry matter percentage in the herbage. The largest response to the application of rock phosphate at the later part of the season is undoubtedly due to the gradual release of P from this source and its accumulation in the soil. On the other hand much of the P in basic slag and superphosphate is in the soluble form and was taken up by the herbage in the earlier part of the season.

The effect of the different sources of P on the available soil P (Morgans' extract) is shown in Table 6.

Table 6: The effect of different sources of P on the available soil P in a grass/clover sward on an organic farm.

Treatment	P applied kg/ha	Soil P concentration mg/kg (Morgan's extract)		
		Before Application	After Application	
			128 days	531 days
No treatment	-	2.10	2.70	2.84
Basic slag 100 kg/ha	7	1.94	3.50	2.44
Basic slag 200 kg/ha	14	2.20	5.70	2.70
Basic slag 400 kg/ha	28	3.22	7.92	4.70
Rock Phosphate 48.4kg/ha	7	2.32	2.80	2.90
Rock Phosphate 96.8kg/ha	14	3.36	5.14	5.68
Superphosphate 43.6kg/ha	7	3.34	5.40	4.24
Superphosphate 87.2kg/ha	14	2.98	5.72	4.64
Superphosphate 174.4kg/ha	28	3.58	9.14	5.82
S.E. (df=36)		0.5050	0.7770	0.7973

The largest increase in the soil P concentrations occurred 128 days after application. Superphosphate at 174.4 kg/ha and basic slag at 400 kg/ha gave the largest increase at this stage. The increase in soil P following applications of basic slag at 200 kg/ha, rock phosphate at 96.8 kg/ha and superphosphate at 87.2 kg/ha were approximately similar. An application of 14 kg/ha of elemental P was applied with each of these treatments. These results show that at this rate of application the response to the three sources is almost equal. Soil analysis carried out after 531 days shows that the available soil P concentration had decreased in all cases except in the case of the plots treated with rock phosphate at 96.8 kg/ha. In this case a slight increase was recorded. This shows that the P supplied by rock phosphate persists for longer in the soil. Due to the less soluble nature of this source of P the build up of elemental P following application is slower initially but the P from this source persists for a longer period due to the slower rate of release.

The effect of the application of the three sources of P on the concentration of P in the herbage is shown in Table 7.

Table 7: The effect of three sources of P on the P concentrations in grass/clover herbage on an organic farm.

Treatment	P applied kg/ha	Herbage P concentration (mg/kg)			
		Before Application	Days After Application		
			35 days	77 days	121 days
No treatment	-	0.34	0.34	0.37	0.39
Basic slag 100 kg/ha	7	0.28	0.30	0.35	0.37
Basic slag 200 kg/ha	14	0.33	0.34	0.38	0.41
Basic slag 400 kg/ha	28	0.35	0.36	0.42	0.48
Rock Phosphate 48.4kg/ha	7	0.28	0.31	0.34	0.36
Rock Phosphate 96.8kg/ha	14	0.33	0.34	0.41	0.44
Superphosphate 43.6kg/ha	7	0.32	0.36	0.43	0.49
Superphosphate 87.2kg/ha	14	0.32	0.38	0.45	0.46
Superphosphate 174.4kg/ha	28	0.34	0.42	0.48	0.52
S.E. (df=36)		0.0187	0.0341	0.0218	

The increases in herbage P which were recorded 35 days after application were small. As time went on the increases became larger but at no stage were very large increases recorded. The largest increases were recorded 121 days after treatment application. The increases recorded were larger following the application of superphosphate compared with basic slag and rock phosphate.

The effect of basic slag and superphosphate application on the P concentration in four different soil types is shown in Table 8.

Table 8: The effect of basic slag and superphosphate on the P concentration in four different soil types

Soil Series	Treatment	P Application (kg/ha)	Soil P concentration (mg/kg)						
			Before Application	Days After Application					
				25	50	75	105	149	200
Screen	Basic slag 100 kg/ha	7.0	10.8	17.5	18.8	15.1	14.1	12.4	12.0
	Superphosphate 43.6 kg/ha	7.0	10.8	20.5	22.1	19.4	14.6	12.8	12.1
Clonroche	Basic slag 100 kg/ha	7.0	13.3	13.8	13.9	14.0	13.5	13.6	13.4
	Superphosphate 43.6 kg/ha	7.0	13.3	15.3	13.9	15.5	13.8	13.5	13.0
Johnstown	Basic slag 100 kg/ha	7.0	2.0	3.1	3.3	3.0	2.3	2.9	2.4
	Superphosphate 43.6 kg/ha	7.0	1.9	4.0	3.6	3.8	1.9	2.3	1.9
Rathangan	Basic slag 100 kg/ha	7.0	1.0	2.1	1.6	1.5	1.1	1.0	1.0
	Superphosphate 43.6 kg/ha	7.0	1.0	1.9	2.1	1.6	1.0	1.0	1.0
S.E. (df =45)			0.2189	0.3446	0.3162	0.2576	0.3511	0.3556	0.3318

The soil P concentration before treatment application was highest in the Clonroche soil. This loam soil was used for tillage for a number of years and high applications of fertilisers were used during this time. The loamy sand Screen soil was also used for cereals and had received high applications of fertilisers during this time. The Johnstown and Rathangan series were more heavy textured soils which were used for grazing and the soil P concentrations were lower. The Screen loamy sand gave the largest increase in soil P following the application of the basic slag and the superphosphate. The P concentration following the application of the superphosphate was slightly higher compared with the basic slag for a period of 75 days after application but there was no difference between the treatments thereafter. Some residual P was present in this soil type 200 days after application of the P treatments. The large increase in available soil P following P application was expected in this light textured soil. Application of P in the form of basic slag or superphosphate gave very little increase in available P concentration in the Clonroche loam. The largest increase (2.2 mg/kg) was recorded 75 days after application of superphosphate. The application of basic slag gave a maximum increase of 0.7 mg/kg in soil P concentration 75 days after treatment application, but the residual effect of basic slag on P concentration was greater than that of the superphosphate. Basic slag and superphosphate application gave only a slight increase in the P concentration of the Johnstown loam. The largest increase in the case of the basic slag was 1.3 mg/kg. This was recorded after 50 days. The largest increase in the case of the superphosphate was 2.1 mg/kg which was recorded 25 days after application. A small amount of residual P was recorded in plots treated with basic slag 200 days after application. No residual P was recorded in plots treated with superphosphate 200 days after application. The Rathangan clay loam showed the least response to soil P application giving a maximum increase of only 1.1 mg/kg in the case of both treatments. This soil had a high clay content and was a strongly buffered soil so that a small increase in available P following application was expected. Due to the high clay content the applied P was rapidly absorbed and no residual P was recorded 105 days after the application of basic slag or superphosphate. The soil concentrations of P at the 0-5 cm depth and a the 5-10 cm depth in the different soils types is shown in Table 9. This table shows that slightly more of the P was concentrated at the 0-5 cm level than at the 5-10 cm level. There was no evidence to show that there was any movement of the P from the 0-5 cm level to the 5-10 cm level during the course of the experiment. There was no evidence that movement of the P in the Screen loamy sand was greater than in the Clonroche and Johnstown loams or the Rathangan clay soil. It was expected that more movement of P would occur in the Screen loamy sand due to the low clay content and the free draining nature of this soil.

Table 9: Effect of soil type on soil P concentration at different depths in the soil profile.

Soil Type	Texture	Sample Depth (cm)	Soil pH	Soil P concentration (mg/kg)						
				Before Treatment	Days After Application					
					25	50	75	105	149	200
Screen	Loamy	0-5	6.8	11.0	19.4	21.4	18.6	14.4	12.9	12.5
	sand	5-10	6.3	10.5	18.6	19.5	15.9	14.4	12.3	11.6
Clonroche		0-5	6.7	13.5	15.3	14.9	15.1	13.9	13.8	13.3
	Loam	5-10	6.6	13.1	13.6	12.9	14.4	13.4	13.4	13.1
Johnstown		0-5	6.9	2.1	4.3	3.9	4.1	2.5	3.1	2.5
	Loam	5-10	6.8	1.8	2.9	3.0	2.6	1.6	2.0	1.8
Rathangan		0-5	6.7	1.0	2.1	1.9	1.9	1.1	1.0	1.0
	Clay loam	5-10	6.8	1.0	1.9	1.9	1.3	1.0	1.0	1.0
S.E. df =45				0.2189	0.3446	0.3162	0.2576	0.3511	0.3556	0.3318

The effect of the two sources of P, basic slag and superphosphate on leaching of P from the 0-5 cm level to the 5-10 cm level is shown in Table 10. The table shows that although the soil P concentration was higher in the soil following the application of the superphosphate there was no evidence that the rate of leaching from the 0-5cm level to the 5-10cm level was greater in the case of the superphosphate compared with the basic slag or that a large degree of leaching occurred at all. These data show that reduction in the soil concentration of available P over time was due to adsorption by the soil rather than to leaching of the P.

Table 10: The effect of fertiliser P source on the soil P concentration at different depths in the soil profile.

Treatment	Sample depth (cm)	Soil P concentration (mg/kg)						
		Before Treatment	Days After Application					
			25	50	75	105	149	200
Basic slag	0-5	6.9	9.4	9.8	9.1	8.0	7.8	7.4
100 kg/ha	5-10	6.6	8.8	8.9	7.8	7.5	7.1	6.9
Superphosphate	0-5	6.9	11.1	11.2	10.8	7.9	7.6	7.2
43.6 kg/ha	5-10	6.6	9.8	9.7	9.3	7.7	7.2	6.8
S.E. (df=45)		0.2189	0.3446	0.3162	0.2576	0.3511	0.3556	0.3318

REFERENCES

ANON. 1991. Council Regulation (EEC) No 2092/91. Official Journal of the European Communities No. L 198/1. 22.7.91. 15 pp.

BOLTON, J. AND COULTER, J.K. 1966. Distribution of fertiliser residues in a forest nursery manuring experiment on a sandy pedsol at Wareham, Dorset. Rep. Forest Res. Forum Comm. London. 1965. 90-92.

BYRNE, E. 1979. Chemical Analysis of Agricultural Materials. An Foras Taluntais, Dublin. 194 pp.

DEVINE, J.R., GUNARY, D., LARSON, S. 1968. Availability of phosphate as affected by duration of fertiliser contact with the soil. J. agric. Sci., Camb. 71. 359-364.

FARRER, K. 1968. Trace elements and magnesium in basic slag and their value to plants. Agri-digest, 15, 3-19.

FASSBENDER, H.W. AND MULLER, L. 1969. Use of silicate amendments in strongly phosphorus fixing soils. II Effects of silica phosphate fertilisers. Turrialba 19, 368-374.

GARDINER, M.J. AND RYAN, P. 1964. Soil Survey Bulletin No. 1. Soils of Co. Wexford. National Soil Survey of Ireland. An Foras Taluntais, Dublin. 171 pp.

GATELY, T.F. 1993. Soil analysis and fertiliser, lime, animal manure and trace element recommendations. Teagasc, Johnstown Castle Research Centre, Wexford. 36 pp.

GERRITSON, H.J. 1967. Long-term trials with phosphatic fertilisers in the Netherlands, Agri. Digest. 10, 3-10.

GIBNEY, N. 1999. Private communication.

HODGES, E.M., KIRK, W.G., DAVIS, G.K. 1968. Effect of phosphate fertilisers on pangolagrass pastures and beef production. Circ.Fla. Agric. Exp. Stn. S-190, 11 pp.

LE CLERG, E.L., LEONARD, W.H. AND CLARK, A.G. 1966. Field Plot Technique. Burgess Publishing Company, Minnesota. 373 pp.

MACNAEIDHE, F.S. 1992. Mineral balance in organic agriculture. In: Potential and Limits of Organic Farming. Eds. Peeters and VanBol. Proc. EU Workshop, Louvain-la-Neuf, Belgium. Commission of European Communities. Brussels. 93-97.

MACNAEIDHE, F.S., LYNCH, M., MURPHY, W.E., FINGLETON, W. AND CODD, F. 1997. A report on the organic farm, Johnstown Castle, Production and Economics, 1990-1995. Teagasc, Johnstown, 85 pp.

MATTINGLY, G.E.C. 1966. Residual value of cumulative dressings of superphosphate, rock phosphate and basic slag on a sandy soil at Wareham, Dorset. Rep. Forest Research Forum. Comm. London, 1965. 93-96.

MATTINGLY, G.E.C. 1968. Evaluation of phosphate fertilisers. II Residual value of nitrophosphates, Gafsa rock phosphate, basic slag and potassium metaphosphate for potatoes, barley and swedes grown in rotation with special reference to changes in soil phosphorus status. J. agric. Sci., Camb. 70, 139-156.

MATTINGLY, G.E.C. AND PENNY, A. 1968. Evaluation of phosphate fertilisers. I Immediate value of dicalcium phosphate, nitrophosphates, Gafsa rock phosphate, basic slag and potassium metaphosphate for barley and rye-grass. J.agric.Sci., Camb. 70. 131-138.

OFORI, C.S. 1968. An evaluation of the direct, residual and cumulative effects of various phosphatic fertilisers on some tropical soils. Ghana J. agric. Sci. 1. 135-142.

SMITH, A.N. 1968. The uptake of phosphorus by wheat and clover from four inorganic soil phosphate fractions after the addition of contrasting types of phosphatic fertilisers. Plant and Soil. 29. 144-155.

STAHLIN, A. 1968. The effect of different forms of phosphate on permanent grassland Z. Acker-u. PflBau 127, 69-84.

THE SCIENCE OF FARMING AND FOOD

EUROPEAN UNION