BLAST FURNACE SLAG AS AN AGRICULTURAL LIMING MATERIAL

By

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INTRODUCTION

Blast furnace slag, a by-product of the steel industry, has been used as an agricultural liming material because it contains limestone residues and usually is available in large quantities at low cost in Baltimore and other steel producing centers. In Maryland alone, approximately 180,000 tons of slag could be prepared for agricultural use each year.

Production of all liming materials (excluding slag) in Maryland increased from 129,296 tons in 1941 to 309,633 tons in 1951 (8). This indicates that the need for lime is well recognized. However, it is estimated that lime use in the State should be nearly doubled.

Many Maryland soils which are very acid have no close supply of liming materials. The cost of transporting lime to these areas increases the price per ton and restricts its use. It is possible that slag produced in Baltimore could be delivered to these localities at one-half the cost of limestone. Slag might, therefore, be of considerable economic importance to farmers of the Eastern Shore and Southern Maryland.

Objectives of Experiment

Previous investigations with blast furnace slag in Maryland and elsewhere have shown considerable variations in crop response to slag treatments. Similar variations in effect of slag on soil acidity and exchangeable cations have been reported. There has also been some indication that the crop producing value of slag is not due entirely to its calcium and magnesium content but may, in part, be due to its content of minor elements.

Because of the possible economic importance of blast furnace slag as an agricultural liming material in certain areas of Maryland, a series of experiments was planned to more fully evaluate this material. Objectives of these experiments were:

(1) To determine the effect of different forms of slag at different rates of application on crop yields under a variety of soil conditions.

(2) To compare the effects of slag and limestone at different rates of application and in different particle sizes on soil pH values and exchangeable cations.

Nature of Blast Furnace Slag

Blast furnace slag available for agricultural use is obtained in the production of pig iron. Iron ore is placed in alternate layers with limestone and coke in the blast furnace. By means of a preheated air blast the coke is burned, producing temperatures of 3000° to 3500° F. Iron oxide is reduced to the metal by carbon of the coke, and limestone is converted to calcium oxide or caustic lime, which combines with silica and other impurities of the ore to form molten slag. Because it is lighter than liquid iron, slag can be drawn off and run through a gutter to a slag dump or can be granulated with cold water.

When molten slag is granulated with water, rapid cooling produces a light-weight, porous, non-crystalline product. Air cooled slag, which cools more slowly on the slag dump, is crystalline, non-porous, and has a greater volume weight than granulated slag.

In the formation of slag, lime is converted to calcium and magnesium silicates. Sulphur, manganese, alumina, small amounts of iron, and certain other trace elements may also be present in the slag.

Composition of the slag varies with the type of ore and flux stone used in the furnace. However, the calcium and magnesium content from any one plant will be fairly uniform as long as the same source of limestone is used. Slags vary from 42 to 50 per cent total oxides.

The blast furnace slags used in these experiments contain little or no phosphorus. They should not be confused with Basic or Thomas Slag or quenched calcium silicate slag produced in the Wilson Dam rock phosphate reduction process. Such slags contain 1 to 3 per cent phosphorus and their phosphorus content may have a considerable effect on crop growth.

REVIEW OF LITERATURE

The value of applying lime to soils of this country has been recognized for many years. Edmund Ruffin (27), a Virginia farmer, wrote an essay in 1852 concerning practical field experiments which he had carried out with calcareous manures. In 1900 Patterson (25) reported on the occurrence and composition of lime in Maryland and later (26) showed the use of lime to be economically feasible for use by farmers.

In searching for cheap sources of lime, investigators and farmers soon turned their attention to blast furnace slag. This material contained the residues of limestone, coke and ore and was available in large quantities at low cost in some areas. It is interesting to note that in 1912 Ames (1) reported blast furnace slag to be of no value either for correcting soil acidity or as a source of phosphorus.

Effect on Lime Requirement

In 1916 Ames and Schollenberger (3) found that blast furnace slag furnishing the equivalent of 8 tons of calcium carbonate per acre was not as effective in reducing the lime requirement of Wooster silt loam soil as 4 tons of precipitated calcium carbonate per acre. However, slag did bring about a reduction in lime requirement. Evidently Ames was still not convinced that blast furnace slag had any use as a liming material, for he reported in another publication (2) that its use as a substitute for limestone on acid soils was not recommended in other than in an experimental way. In the same article, he also stated that blast furnace slag and calcium silicate produced more clover than calcium carbonate in pot tests.

Further investigation of the effect of slag in reducing the lime requirement was carried out by Schollenberger (28) in 1921. He reported slag to be less reactive with soil than either calcium carbonate or pure calcium silicate. A report of the Ohio Agricultural Station (24) in 1926 indicated that one ton of granulated slag reduced the lime requirement 519 pounds, while one ton of ground limestone reduced the lime requirement 1333 pounds. It was also reported that grinding more than doubled the effectiveness of this slag, but its value was still only 61 per cent as great as ground limestone in plot experiments and 43 per cent as great in cylinder experiments.

Effect of Dicalcium Silicate

At approximately the same time that investigations were begun with blast furnace slag as a source of calcium and magnesium, other investigators became interested in the effect of dicalcium silicates on acid soils. MacIntire and Willis (19) in 1914 compared silicates and carbonates as sources of lime and magnesia for plants but did not reach any conclusions as to the effectiveness of these materials. Hartwell and Pember (15) in 1920 found that dicalcium silicate was as effective as limestone in counteracting toxic conditions in acid soil, but also stated that there was no justification for assigning extra value to this material because of its silicon content.

At about the same time Conner (11) found that dicalcium silicate produced good crops on an acid black sand while lime alone did not produce good crops. He attributed the better growth to more complete precipitation of iron and aluminum by the silicate. Schollenberger (29) showed that various silicates including dicalcium silicate and blast furnace slag increased the percentage of silica in soybeans, oats and buckwheat, while calcium carbonate appeared to lessen the amount taken up. In pot experiments he found that the silicate materials produced larger yields than did calcium carbonate. Shedd (31) reported that calcium and magnesium silicates increased yields of soybean hay, oats, sweet clover and alfalfa.

In the period from 1924 to 1926, Barnette (5), (6), (7) reported a series of experiments with calcium silicates. He concluded that the artificial calcium silicates were as effective as the common forms of lime in counteracting soil acidity if applied on the basis of equivalent amounts of calcium oxide. He also reported that dicalcium silicate made an exceptional increase in the growth of barley which might be due to absorption of silicon by the plant. Ground limestone, calcium hydrate and calcium silicate were all found to have an effect in increasing the numbers of bacteria in the soil.

MacIntire et al (17) in 1934 indicated, as a result of lysimeter studies, that there was less loss of calcium from soils treated with calcium silicate than from soils treated with limestone and burnt lime. Cook and Conner (12) in 1936 concluded that calcium silicates were better neutralizers of the acidity developed by fertilizers in soil than were dolomite, calcium carbonate or rock phosphate.

Slag from Rock Phosphate Reduction Furnaces

MacIntire and associates conducted a series of experiments (18), (20), (21), (22) with calcium silicate slags which are by-products of the electric furnace rock phosphate reduction process. Since this material contains approximately two per cent P_2O_5, the results obtained in crop yields were undoubtedly influenced by the phosphorus content of the slag. Therefore, yield results of these experiments cannot readily be compared with experiments using blast furnace slag which contains only a trace of phosphorus.

Certain conclusions of MacIntire et al do have some applications, however. Quenched calcium silicate slag was found to be superior to air cooled slag in its effect on crop yields and pH. Quenched slags produced soil pH values in the range 6.2 to 6.8 while air cooled slags produced pH values between 5.8 and 6.2. Decrease in particle size of slag was found to induce higher soil pH values.

Effect of Slag on Crop Yields

In 1928 White (32) carried out experiments with blast furnace slag on a Dekalb soil in Pennsylvania. One ton of 20 mesh slag was not as effective as one ton of 20 mesh limestone in increasing yields of corn, oats, barley, bluegrass hay and soybean hay, but did produce more timothy hay. Slag meal (87 per cent through a 100 mesh screen) had greater effect than 20 mesh limestone on yields of oats and timothy, nearly equal effect on yields of bluegrass hay, soybean hay, and corn, and less effect on barley yields. 200 mesh slag was reported to be nearly as effective as 200 mesh limestone on yields of clover hay.

Wiancko et al (34) conducted liming experiments on Newton fine sandy loam in Indiana in which blast furnace slag was included. The value of the crop increases produced by 4 tons of blast furnace slag per acre applied to a rotation of corn, oats and hay was $44.90. Four tons of 10 mesh limestone produced crop increases valued at $65.85.

Crane (13) in 1930 compared slag and limestone in greenhouse and laboratory tests. He reported that on the gross ton basis, 100 mesh limestone was somewhat superior to 100 mesh slag in its effect on red clover and on soil reaction. On the basis of calcium carbonate equivalence (as determined by titration using phenolpthalein as indicator) the two had nearly the same effectiveness. Crane also reported that 4 ton applications of granulated slag with only 35 per cent passing a 40 mesh screen gave approximately the same results as one ton of 100 mesh slag.

White et al (33) conducted a rather extensive series of field and laboratory studies with blast furnace slag over the period from 1926 to 1934. These investigations indicated that "3 tons of agricultural slag (granulated), 1.75 tons of 20 mesh slag, 1.55 tons of fine slag, and 3 tons of air cooled slag screenings each produced total yields of hay and grain which were not significantly different from the yields produced by 1.5 tons of 80 mesh limestone". On the basis of their experiments on Dekalb soil, they conclude that blast furnace slag has the same crop producing value as pulverized limestone in equivalent amounts and of similar fineness.

Carter et al (10), in recent work on soils of Alabama stated that in most cases slag was as efficient in crop production as limestone of similar fineness if applied in equivalent amounts. On two soils slag plus borax produced yields of alfalfa as good as those from limestone plus borax. Carter reported that the yield of alfalfa was greater on two soils from a treatment of 4 tons of slag than from a treatment of 2 tons of slag. Moreover, his experiments showed that 4 tons of slag were required to produce the same amount of exchangeable calcium in the soil as 2 tons of limestone. This investigation also pointed out that the minor elements in slag are not in sufficient supply to replace the minor element fertilizers recommended for minor element deficient soils.

EXPERIMENTAL PROCEDURE

Field Experiments

Nine different locations representing the important agricultural areas of the state were chosen for survey-type field experiments. At each location slag of different grades of fineness was applied to the soil at varying rates. On the Monmouth loamy sand soil at Marlboro limestone was applied at rates containing amounts of total oxides equivalent to that contained in slag applications. Crop yields were determined, and measurements were made of exchangeable cations in the soil and of soil pH values.

Soil Types

The soils at these locations differed widely in profile characteristics. Table I shows the location and soil type of each of the test plots. Figure I shows the approximate location of these plots on an outline map of the state.

Table I

Location and Soil Type of Experimental Plots

Farm Location by Towns	County	Soil Type
Princess Anne	Somerset	Mattapex silt loam
Salisbury	Wicomico	Matawan sandy loam
Cordova	Talbot	Matawan sandy loam
Chestertown	Kent	Sassafras silt loam
Marlboro	Prince George	Monmouth loamy sand
Jarrettsville	Harford	Glenelg loam
Sparks	Baltimore	Chester silt loam
Frederick	Frederick	Duffield silt loam
Hagerstown	Washington	Emory silt loam

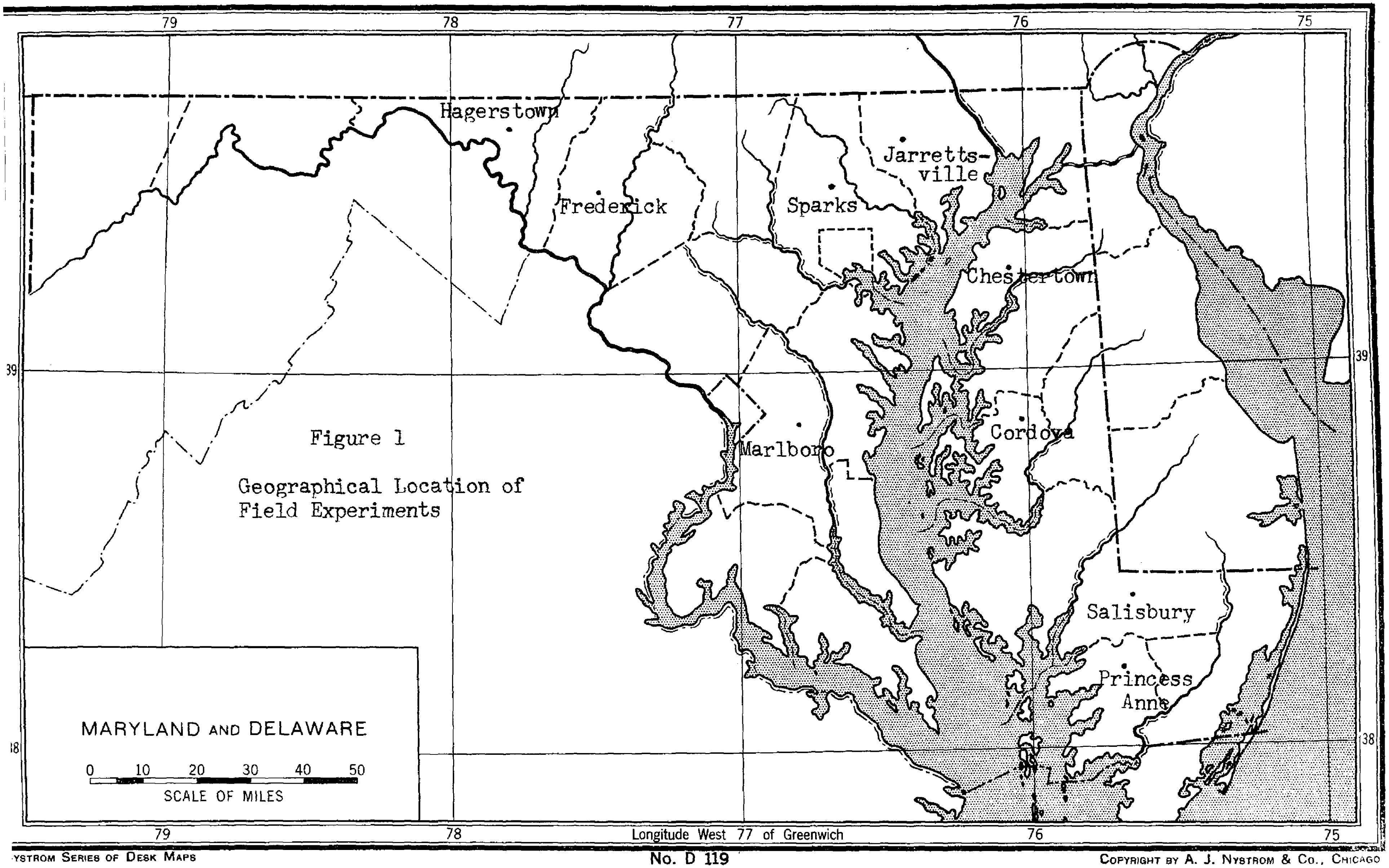

Figure 1

Geographical Location of Field Experiments

Table 2 presents the chemical analyses of surface soil at each location prior to the application of slag or limestone.

Table 2

Exchangeable Cations and Total Exchange Capacity of Surface Soil on Plot Areas Prior to Treatment*

Soils and Location	Exchangeable Ions - m.e./100 g					Total Exchange Capacity m.e./100 g
	H	Ca	Mg	Mn	K	
Mattapex silt loam (Princess Anne)	6.22	2.61	0.57	0.02	0.09	9.51
Matawan sandy loam (Salisbury)	1.26	2.01	0.86	0.00	0.08	4.21
Matawan sandy loam (Cordova)	2.48	1.85	0.31	0.00	0.20	4.84
Sassafras silt loam (Chestertown)	2.42	4.08	0.87	0.12	0.08	7.57
Monmouth loamy sand (Marlboro)	4.47	5.37	0.63	0.03	0.71	11.21
Glenelg loam (Jarretsville)	4.07	3.90	0.69	0.02	0.20	5.88
Chester silt loam (Sparks)	6.13	7.47	0.90	0.09	0.60	15.19
Duffield silt loam (Frederick)	1.21	7.32	1.25	0.01	0.34	10.13
Emory silt loam (Hagerstown)	1.35	7.59	0.70	0.07	0.25	9.96

*Methods of analysis are presented on page 21

<u>Liming Materials</u>

Three different types of blast furnace slag were used in these experiments. The first type was air cooled slag which is obtained by pouring molten slag from the blast furnace into pits in layers and allowing it to cool. The hardened mass is removed from the pit by power shovel, and is crushed and screened to produce a material for agricultural use. Air cooled slag was tested at all nine locations and was used in pot experiments.

Two other types of slag were tested at a smaller number of locations. These were granulated manganese slag and foamed slag. Granulated manganese slag is obtained as a by-product in the production of ferro-manganese iron. The molten slag is completely quenched in cold water and produces a granular product most of which will pass a one-eighth inch seive.

Foamed slag is prepared by treating the molten slag with controlled jets of water as the slag is dumped. This produced a non-crystalline porous material of very light weight.

Ground limestone was used in the experiment at Marlboro and in the greenhouse experiments in order to compare the results produced by slag and limestone.

Mechanical analyses of the liming materials used in field experiments are shown in Table 3. In all references to field experiments the various size grades are designated by the per cent of material passing a 100 mesh screen.

Table 3

Mechanical Analyses of Liming Materials Used in Field Experiments

B & S** Screen Size	Per Cent Passing Various Screen Sizes — Grade #1: Air Cooled Slag	Grade #1: Granulated Manganese Slag	Grade #1: Limestone	Grade #2: Air Cooled Slag	Grade #2: Granulated Manganese Slag	Grade #2: Foamed Slag	Grade #2: Limestone	Grade 3: Air Cooled Slag	Grade #4: Air Cooled Slag	Grade #4: Granulated Manganese Slag	Grade #4: Foamed Slag	Grade #4: Limestone	Grade 5: Air Cooled Slag
4	100.0	100.0	100.0	100.0	100.0	98.8	100.0	100.0		100.0			
6	97.6	98.6		99.0	98.8	96.2	99.4	99.4		99.8			
8	85.6	91.2	83.3	92.6	93.4	81.0	92.0	95.0		99.0			
10	80.0	85.4		88.2	89.0		84.8	92.2		98.4			
16	62.4	57.0		73.6	67.2	50.0	66.2	83.2		94.0			
20	51.4	37.6		63.6	50.8	42.4	55.4	77.6		90.6		100.0	
30	42.2	25.4	40.5	56.0	39.8	40.0	47.4	73.2	100.0	88.4		99.5	
40	34.0	19.0		49.4	33.4	38.4	41.6	69.6	99.8	87.0	100.0	99.0	
50	26.6	15.6		43.4	29.8	36.8	36.0	66.0	98.8	86.0	98.5	97.5	
60	22.8	14.4		39.8	28.4	35.4	33.4	63.2	96.4	85.2	96.5	94.5	
80	18.0	13.4	27.0	34.6	26.8	31.6	29.8	57.8	89.8	83.6	88.0	96.0	100.0
100	14.6	12.6	22.6	29.4	25.8	27.2	27.2	50.6	79.0	81.2	78.0	77.5	99.3
200	8.4	10.6		18.0	21.8	15.4	20.4	32.0	51.6	70.6	45.5	50.5	92.5

* Analysis supplied by The National Slag Association

** Abbreviation for Bureau of Standards

Chemical analyses of the various liming materials are presented in Table 4. It can be seen that appreciable quantities of calcium and magnesium are present in the slag, giving the slag a computed calcium carbonate equivalence of eighty to ninety per cent. Sulfur, iron, manganese and other trace elements may also be present in slag. Boron is present in slag in very small quantities, a ton supplying 0.2 pounds per acre or less.

Rates of Application

Bray and DeTurk (9) found that the sum of the calcium and magnesium held on the exchange capacity of the soil at or near neutrality. As a starting point in this experiment this criterion was assumed to be the optimum condition.

Assuming complete solubility of liming materials and complete adsorption of calcium and magnesium by the exchange complex, a calculation was made of the amount of slag or limestone required to increase the exchangeable calcium and magnesium content of the untreated soils to 80 per cent of the total exchange capacity. Again, assuming complete solubility, enough slag to give a 160 per cent saturation of the total exchange capacity was applied in a second treatment. This gave two levels of chemically equivalent weights of the various materials so that the effect of quantity could be observed on the soil and on crop yields. In the cases of the Emory and Duffield silt loams the soil already had and 80 per cent saturation of the exchange complex. In these instances, the lighter treatments were omitted and only the heavier applications were made. Rates of application of slag for each soil appear in Tables 65 - 78 in the Appendix.

Table 4

Chemical Analyses of Liming Materials *

Material	Per Cent							Loss on Ignition	Computed $CaCO_3$ Equivalence
	SiO_2	Al_2O_3	CaO	MgO	S	FeO	MnO		
Air Cooled slag	34.83	16.73	36.00	6.00	1.35	1.11	1.17	1.03	79.10
Granulated Manganese slag	22.28	20.98	32.70	8.73	1.19	1.30	7.57	2.86	80.04
Foamed slag	34.11	14.45	42.25	6.21	1.20	0.65	1.83	0.00	89.59
Limestone	3.10	0.92	53.29	0.81	0.06	0.45	——	41.02	97.13

* Analysis supplied by the National Slag Association

Table 5

Location of Field Plots, Soil Type, and Crops Grown

Farm Location by Town	Soil Type	First Year Crop - 1947	Second Year Crop - 1948	Third Year Crop - 1949
Princess Anne	Mattapex silt loam	Wheat	Clover-timothy	Pasture
Salisbury	Matawan sandy loam	Clover	Corn	Corn
Cordova	Matawan sandy loam	Corn	Wheat	Pasture
Chestertown	Sassafras silt loam	Corn	Wheat	Clover-timothy
Marlboro	Monmouth loamy sand	——	Alfalfa seeded	Alfalfa[1]
Jarrettsville	Glenelg loam	Clover-timothy	Corn	Wheat
Sparks	Chester silt loam	Corn	Wheat	Wheat
Frederick	Duffield silt loam	Clover	Corn	Barley
Hagerstown	Emory silt loam	Clover-timothy	Corn	Wheat

[1] Alfalfa yields were determined in 1949, 1950 and 1951.

Table 6

Method and Time of Application of Liming Materials in Field Experiments

Soil and Location	Method of Application	Date of Application
Mattapex silt loam Princess Anne	Top dressing to wheat.	April 26, 1947
Matawan sandy loam Salisbury	Top dressing to hay.	May 2, 1947
Matawan sandy loam Cordova	Broadcast on plowed field and disked in.	April 27, 1947
Sassafras silt loam Chestertown	Broadcast on plowed field and disked in.	May 5, 1947
Monmouth loamy sand Marlboro	One-half disked in and plowed under. Second half then broadcast and disked in.	August 25, 1948
Glenelg loam Jarretsville	Top dressing to hay.	May 19, 1947
Chester silt loam Sparks	Broadcast and plowed under.	April 11, 1947
Duffield silt loam Frederick	Top dressing to hay.	April 18, 1947
Emory silt loam	Top dressing to hay.	May 10, 1947

Figure 2

Representative Field Plot Design Showing Arrangement of Plots, Type of Slag, and Rate of Application

F-27.0-H	F-27.0-M		S-14.6-M
F-76.3-H	F-76.3-M	S-14.6-H	
F-27.0-M	F-27.0-H		S-27.5-M
F-76.3-M	F-76.3-H	S-27.5-H	
*	S-14.6-M		S-50.6-M
S-14.6-H		S-50.6-H	
	S-27.5-M		S-79.4-M
S-27.5-H		S-79.4-H	
	S-50.6-M		S-99.3-M
S-50.6-H		S-99.3-H	
	S-79.4-M	Untreated	Untreated
S-79.4-H			S-14.6-H
	S-99.3-M	S-14.6-M	
S-99.3-H			S-27.5-H
Untreated	Untreated	S-27.5-M	
	S-14.6-H		S-50.6-H
S-14.6-M		S-50.6-M	
	S-27.5-H		S-79.4-H
S-27.0-M		S-79.4-M	
	S-50.6-H		S-99.3-H
S-50.6-M		S-99.3-M	
	S-79.4-H	F-27.0-H	F-27.0-M
S-79.4-M		F-76.3-H	F-76.3-M
	S-99.3-H	F-27.0-M	F-27.0-H
S-99.3-M		F-76.3-M	F-76.3-H

*Unlettered plots contained treatments not used in this study.

S refers to air-cooled slag
F refers to foamed slag
H refers to heavy rate of application
M refers to medium rate of application
Center figure refers to per cent of slag passing 100 mesh screen.

Field Experimental Plots

The location, soil types, and crops of the test farms are shown in Table 5.

It was impossible to keep the method and time of application as invariables since the cooperating farms were under entirely different systems and farming practices. The method of application was necessarily changed in order to fit into the schedule and methods practiced by the individual farmers. Table 6 presents a summary of the application, methods and time of application.

Figure 2 shows the type of plot design used in this experiment. While plot patterns on all farms were similar, they were varied slightly depending on the number of slag materials used at that location. Plots were virtually one-hundredth of an acre, being 14 feet wide and 31 feet long. The treatments were not randomized but were placed in a regular order. Each treatment was replicated four times at each location.

On the Monmouth soil, air cooled slag was compared with equivalent amounts of pulverized limestone. The plot design for this experiment is presented in Figure 3.

Figure 3

Plot Design Showing Arrangement of Field Plots, Fineness of Slag and Limestone, and Rate of Application on Monmouth Loamy Sand Soil

S-14.6-M		S-14.6-M	
L-22.6-M	S-79.4-H	L-22.6-M	S-79.4-H
S-50.6-M		S-50.6-M	
Untreated	S-50.6-H	L-27.2-M	S-50.6-H
L-27.2-M	L-77.5-H	S-79.4-M	L-77.5-H
S-79.4-M	S-14.6-H	L-77.5-M	S-14.6-H
L-77.5-M	L-27.2-H		L-27.2-H
*	L-22.6-H		L-22.6-H
	Untreated	S-14.6-H	
S-14.6-H		L-22.6-H	S-79.4-M
L-22.6-H	S-79.4-M	S-50.6-H	
S-50.6-H		Untreated	S-50.6-M
L-27.2-H	S-50.6-M	L-27.2-H	L-79.4-M
S-79.4-H	L-77.5-M	S-79.4-H	Untreated
L-77.5-H	S-14.6-M	L-77.5-H	S-14.6-M
	L-27.2-M		L-27.2-M
	L-22.6-M		L-22.6-M

*Unlettered plots have other treatments not used in this study.

S refers to air-cooled slag
L refers to limestone
M refers to medium rate of application
H refers to heavy rate of application
Center number in each plot refers to per cent of material passing 100 mesh screen.

Soil Sampling

One replicate of each treatment was sampled for chemical analysis. The first sampling of soil was undertaken two to four months after treatment, which was usually after two or more good rains. Soil sampling was repeated at one, two, and three year intervals following treatment. Representative surface soil samples were collected by the method advocated by the A.O.A.C. (4) and were brought to the laboratory for analysis. These samples were taken with a soil auger at a depth of 0 to 6 inches.

Chemical Analyses

To investigate the affects of slag treatments on the replaceable cations and the pH values, the following procedure was used. The soil samples were air dried, were passed through a 10 mesh screen, and were mixed to give a uniform sample.

pH values were determined with a Beckman pH meter using a 2:1 soil to water ratio as outlined by Mason and Obenshain (23).

Exchangeable cations were removed from the soil by the ammonium acetate leaching method of Schollenberger and Simon (30). Schollenberger's procedure was also employed for the determination of exchangeable hydrogen, calcium and manganese. Magnesium was determined by the titan yellow method advocated by Gillam (14). Determination of potassium was made by use of the Beckman flame photometer.

Measurement of the total exchange capacity of the soil was made as follows. The soil was first saturated with potassium by leaching 50 grams of soil with 500 ml. of one normal potassium chloride. Excess potassium was removed by washing the soil with alcohol until no test for chlorides was obtained. The exchangeable potassium was then displaced by ammonium ions and subsequently determined by use of the Beckman flame photometer.

All analyses for pH and exchangeable cations were carried out on duplicate samples.

The pH values were determined on soil samples taken in 1947, 1948, 1949 and 1950. Exchangeable hydrogen, calcium, magnesium, manganese and potassium were determined for all soils in the year that slag was applied. Hydrogen, Calcium, magnesium and manganese were determined on the 1947, 1948 and 1949 samples of Sassafras silt loam.

Since no effect of slag treatments was observed on the exchangeable potassium in the first soil sampling, the analysis for this element was omitted in subsequent years.

Crop Yields

Crop yields were determined on each plot in order to study the influence of the various treatments. Yield data was obtained at all locations over a three year period except for the Glenelg soil where only two year's results were obtained.

Both the corn and hay yields were corrected to a twenty per cent moisture basis.

All crop results reported are an average of four replicates. However, these plots were not randomized. For this reason statistical treatment could not be applied to the results.

Greenhouse Experiments

In order to obtain additional information concerning the effect of slag on soil pH and exchangeable cations as compared with the effect of limestone, a greenhouse pot experiment was set up.

Soil Types

Three soils, representing extremes in texture, were selected from the group of soils used in field experiments. The soils selected were Mattapex silt loam, Glenelg loam, and Monmouth loamy sand. Chemical data concerning these soils is presented in Table 2.

Liming Materials

Air cooled slag and limestone were used in these experiments. The characteristics and chemical analyses of these materials have been presented on pages 12 and 14 respectively.

For this experiment the liming materials were separated into groups of definite particle sizes by dry screening through a nest of standard screens. By this method, five different size groups were obtained. The size limits of each group are shown in the following table.

Table 7

Particle Size Groups of Liming Materials Used in Greenhouse Experiments

Group	Liming Material	
	Passing B. of S. Screen No.	Retained on B. of S. Screen No.
1	4	10
2	10	20
3	50	60
4	80	100
5	200	

In reporting results of greenhouse experiments, these groups will be designated by the limiting screen sizes, e.g. 4-10.

Three of the groups - 10-20 mesh, 50-60 mesh, and 80-100 mesh - were tested on all three soils mentioned above. The 4-10 mesh group and the finer than 200 mesh group were tested only on the Monmouth soil.

Rates of Application

Rates of application of liming materials were 80 and 160 per cent of the base exchange capacity as explained on page 14. Amounts applied to individual soils appear in Tables 79-84 in the Appendix.

Method of Application

Soils were first air dried and were then passed through a 10 mesh screen. To 1500 grams of soil, a calculated amount of liming material of the desired fineness was added and the two were thoroughly mixed. The soil was then placed in an earthenware pot 6 inches in diameter and 5 inches deep. Each pot had a hole at its base to permit drainage.

Design

A diagram of the kinds of materials, fineness of materials and rates of application for one soil is presented in Figure 4.

Figure 4

Schematic Diagram of Greenhouse Experiment

Soil	Material	Fineness	Rate of Application	Pots
Monmouth Loamy Sand	Slag	10-20 mesh	Low	Pot 1 Pot 2
			High	Pot 1 Pot 2
		48-60 mesh	Low	Pot 1 Pot 2
			High	Pot 1 Pot 2
		80-100 mesh	Low	Pot 1 Pot 2
			High	Pot 1 Pot 2
	Limestone	10-20 mesh	Low	Pot 1 Pot 2
			High	Pot 1 Pot 2
		48-60 mesh	Low	Pot 1 Pot 2
			High	Pot 1 Pot 2
		80-100 mesh	Low	Pot 1 Pot 2
			High	Pot 1 Pot 2
	Untreated	——	None	Pot 1 Pot 2

Greenhouse Procedure

Pots were placed in random arrangement in the greenhouse and were initially watered with equal quantities of distilled water. Equal quantities of water were added to all pots whenever the soil began to dry out. On several occasions it was necessary to remove the soil from the pots and screen it in order to prevent the soil from cracking and shrinking away from the sides of the pot.

At the end of 10 months, the soil was removed from each pot, and was screened, thoroughly mixed and sampled. Measurements were made of soil pH and of exchangeable hydrogen, calcium, and magnesium, by methods previously described on page 21.

Soils were replaced in the pots. To further simulate field conditions five sunflower plants were grown in each pot. Because factors other than treatments influenced growth, yields were not studied. Pots were watered as before. At the end of four months soil samples were taken and pH measurements were made.

RESULTS

Because of the great volume of data collected in this series of experiments, individual plot or pot results for each location or soil are included in the appendix. Tables summarizing the various phases of investigation are presented in the following pages in conjunction with the discussion of results. Greenhouse and field experiments are discussed concurrently.

Chemical Determinations

Soils

The soils used in both greenhouse and field tests were found to be significantly different after treatment in pH and in exchangeable calcium, magnesium, and hydrogen. Even if liming materials had dissolved and had been completely adsorbed by the exchange complex, significant differences would have occurred between soils in the exchangeable calcium, magnesium and hydrogen tests. These differences would exist because the soils varied in exchange capacity and the test results were recorded in terms of milliequivalents rather than as percentage base saturation.

However, in the case of pH measurements made at the low rate of application, soils probably would not have shown significant differences if all the liming materials had been completely dissolved and adsorbed, so that 80 per cent saturation was reached. The pH of soils could be the same if soils contained the same type of clay and organic matter and had the same base saturation.

If complete solution of liming materials occurred at the heavy rate of application, pH measurements should show significant differences. In this case pH should depend largely on dissociation of liming materials because there would be excess calcium and magnesium in the soil solution.

Materials

Conclusions concerning differences between slag and limestone with respect to chemical responses in the soil are based on greenhouse studies. In these tests slag and limestone produced changes in exchangeable cations that were significantly different. Conversely, Table 8 shows that for pH determinations, materials were not significantly different when tested with rates x materials interaction. It appears upon examination of the data (Table 8) that the small changes in pH values produced by liming treatments on Glenelg soil and wide variations in pH at different sampling dates on this soil are responsible for the failure to obtain significant differences in materials.

Since there was such a large interaction between materials and rates, and since this interaction was used to test significance, there is little indication from this experiment that limestone and slag will produce similar changes in pH values of soils other than those tested. For Monmouth, Glenelg and Mattapex soils, however, the slag and limestone produced significant increases in pH.

Table 8 shows that air cooled slag was only half as effective as limestone in increasing soil pH. Slag produced an average increase of one-half a pH unit while limestone produced an increase of one pH unit.

Correlated with the increase in pH was the decrease in exchangeable hydrogen. Slag treatments decreased exchangeable hydrogen by 1.3 m.e. per 100 grams of soil while limestone decreased this cation by 2.2 m.e. per 100 grams (see Table 9). Here, again, slag had approximately one-half the effect of limestone.

Also correlated with increase in pH is the increase in exchangeable calcium as shown in Table 10. The average increase produced by slag treatments was 1.2 m.e. per 100 grams of soil while the increase produced by limestone was [illegible] m.e. per 100 grams of soil. Limestone was slightly more than twice as effective as slag in this case. Carter et al (10) reported similar increases in exchangeable calcium in soils treated with slag in Alabama.

In Table 18 the effect of the liming materials on exchangeable magnesium is presented. This table shows that slag produced an increase of 0.4 m.e. per 100 grams of soil while limestone produced only 0.2 m.e. increase. The slightly greater effect of slag in this case was probably due to the fact that slag had a magnesium oxide content of 6.00 per cent while limestone had a magnesium oxide content of only 0.81 per cent.

With the exception of its effect on magnesium, slag has been only half as effective as limestone in changing pH and exchangeable calcium and hydrogen. It would appear, therefore, that the solubility of air cooled slag is approximately one-half that of calcitic limestone. This agrees with the finding of Ames and Schollenberger (3), Schollenberger (28) and other work at the Ohio Agricultural Experiment Station (24).

Tables 8, 9 and 10 show that for pH, exchangeable hydrogen and calcium, there was an interaction between soils and materials. This means that the liming materials produced different responses to these tests on the various soils. Greatest response to the liming materials occurred on Monmouth and Mattapex soils. Glenelg soil showed least response. For this interaction limestone treated soils had the highest pH and exchangeable calcium and lowest exchangeable hydrogen measurements in all cases.

It is difficult to account for less response to all liming materials on Glenelg soil than on Monmouth and Mattapex soils. A probable explanation is the fact that this soil had a higher initial pH, a much higher initial concentration of exchangeable calcium, and a lower initial concentration of exchangeable hydrogen. The presence of the basic ions and the low acidity may have inhibited dissolution of the liming materials. The reverse of this process would account for greater response on the more acid Monmouth and Mattapex soils.

Table 8

Average Effect of All Air Cooled Slag and Limestone Treatments on Soil pH Values in Greenhouse Experiments

Soil	Material			Average for Soil
	Untreated	Slag	Limestone	
Monmouth loamy sand	4.96	5.79	6.46	6.04
Glenelg loam	6.28	6.43	6.68	6.53
Mattapex silt loam	4.46	4.97	5.44	5.15
Average for Materials	5.23	5.73	6.19	

L.S.D. Soils (including untreated soils) = 0.47

L.S.D. Soils x Materials (including untreated soils) = 0.36

L.S.D. Soils x Materials (excluding untreated soils) = 0.19

Materials not significant when tested with rates x materials interaction.

Table 9

Average Effect of All Air Cooled Slag and Limestone Treatments on Milliequivalents of Exchangeable Hydrogen Per 100 Grams of Soil in Greenhouse Experiments

Soil	Material			Average for Soil
	Untreated	Slag	Limestone	
Monmouth loamy sand	3.20	1.62	0.63	1.29
Glenelg loam	1.84	1.20	0.84	1.08
Mattapex silt loam	7.41	5.68	4.44	5.24
Average for Material	4.15	2.84	1.97	

L.S.D. Soils (including untreated soils) = 0.21

L.S.D. Materials (including untreated soils) = 0.33

L.S.D. Soils x Materials (including untreated soils) = 0.57

L.S.D. Soils x Materials (excluding untreated soils) = 0.30

Table 10

Average Effect of All Air Cooled Slag and Limestone Treatments on Milliequivalents of Exchangeable Calcium Per 100 Grams of Soil in Greenhouse Experiments

Soil	Material			Average for Soil
	Untreated	Slag	Limestone	
Monmouth loamy sand	4.20	5.01	7.24	5.96
Glenelg loam	9.27	10.03	11.20	10.51
Mattapex silt loam	3.26	5.17	7.61	6.15
Average for Material	5.58	6.74	8.69	

L.S.D. Soils (including untreated soils) = 0.28

L.S.D. Materials (including untreated soils) = 2.87

L.S.D. Materials (excluding untreated soils) = 1.08

L.S.D. Soils x Materials (including untreated soils) = 0.78

L.S.D. Soils x Materials (excluding untreated soils) = 0.42

Rates of Application

Tables 11 to 14 inclusive, summarize the effect of the two rates of application used in greenhouse experiments. An examination of Table 11 will show that more liming material was needed to bring these soils to neutrality than was applied in this experiment. It was assumed in calculating the rates of application that the liming materials would be completely soluble and that calcium and magnesium would be completely adsorbed by the clay. Of course these assumptions did not hold true. The liming materials dissolved at comparatively slow rates and did not bring about the calculated changes in pH and exchangeable ions over the period of time studied.

pH values (Table 11) for the various rates of application of combined liming materials in greenhouse experiments were not significantly different because the large rates x materials interaction was used as a test of significance. The failure to obtain significant differences in pH between rates of application may be due to the small changes in pH produced by liming treatments on Glenelg soil and the wide variations in pH at different sampling dates on this soil. However, if the error term is used as a test of significance, rates of application may be considered significantly different for pH measurements on these particular soils.

Exchangeable calcium, hydrogen and magnesium tests (Tables 12-14) showed significant differences between the two rates of application of liming materials used in greenhouse studies. The averages for rates of application in these tables show, for slag and limestone combined, that the high rate of application produced about twice the effect of the low rate in changing pH and exchangeable cations. It is interesting to note that the high rate was only twice as effective, even though it supplied three or four times as much total oxides to the soil. In explanation it may be pointed out that these greenhouse tests were continued for only fourteen months. The relative effect of the high rate of application might be greater over longer periods of time.

Tables 15 to 18 inclusive present the effects of slag and the effects of limestone at different rates of application. In the case of both slag and limestone the high rate of application was approximately twice as effective as the low rate. This agrees with previous observations concerning the over-all effect of rates.

As previously indicated there was a significant interaction between rates and materials for all tests except for exchangeable calcium. This interaction indicates that the two materials produced different responses at different rates of application. However, these differences in response were small when judged from an agronomic viewpoint.

Slag was approximately one-half as effective as limestone at both low and high rates in changing soil pH, exchangeable hydrogen, and exchangeable calcium (Tables 15, 16, 17). Slag was slightly more effective than limestone at both rates of application (Table 18) in increasing exchangeable magnesium because of its higher magnesium content.

In field experiments, the effects of rates of application of slag alone are presented in Tables 19 to 22 inclusive. In the tests for pH, exchangeable hydrogen, and exchangeable calcium, significant differences occurred between the different rates of application. Table 22 shows that significant differences did not occur between rates of application for the exchangeable magnesium test. Failure to obtain differences in this case may be explained in this way. Only small quantities of magnesium were present in all soils and there was probably considerable variation in magnesium content of individual plots before treatment. The relatively small amounts of magnesium added by the slag were not enough to eliminate the variations between plots. In addition the chemical test for magnesium was not as accurate as tests for the other elements.

The high rate of application of slag in field tests was approximately twice as effective as the low rate in changing pH and exchangeable ions. While this agrees with the results of greenhouse studies, the changes produced by slag treatments in the field were less, in most cases, than in the greenhouse.

Table 11

Average Effect of Rate of Application of All Liming Materials on pH Values of Soils Tested In Greenhouse Experiments

Soil	Rate of Application			Average for Soil
	Untreated	Low	High	
Monmouth loamy sand	4.96	5.77	6.48	6.04
Glenelg loam	6.28	6.44	6.67	6.53
Mattapex silt loam	4.46	4.91	5.50	5.15
Average for Rate	5.23	5.71	6.21	

L.S.D. Soils (including untreated soils) = 0.47

L.S.D. Rates x Soils (excluding untreated soils) = 0.19

L.S.D. Rates x Soils (including untreated soils) = 0.36

Rates not significant when tested with rates x materials interaction.

Table 12

Average Effect of Rate of Application of All Liming Materials on Milliequivalents of Exchangeable Hydrogen Per 100 Grams of Soil in Greenhouse Experiments

Soil	Rate of Application			Average for Soil
	Untreated	Low	High	
Monmouth loamy sand	3.20	1.60	0.66	1.29
Glenelg loam	1.84	1.35	0.68	1.08
Mattapex silt loam	7.41	5.94	4.19	5.24
Average for Rate	4.15	2.96	1.84	

L.S.D. Soils (including untreated soils) = 0.21

L.S.D. Rates (including untreated soils) = 0.33

L.S.D. Rates x Soils (including untreated soils) = 0.57

L.S.D. Rates x Soils (excluding untreated soils) = 0.30

Table 13

Average Effect of Rate of Application of All Liming Materials On Milliequivalents of Exchangeable Calcium Per 100 Grams of Soil in Greenhouse Experiments

Soil	Rate of Application			Average for Soil
	Untreated	Low	High	
Monmouth loamy sand	4.20	5.00	7.25	5.98
Glenelg loam	9.27	10.03	11.20	10.51
Mattapex silt loam	3.26	5.44	7.35	6.15
Average for Rate	5.58	6.82	8.60	

L.S.D. Soils (including untreated soils) = 0.28

L.S.D. Rates (including untreated soils) = 2.87

L.S.D. Rates (excluding untreated soils) = 1.08

L.S.D. Rates x Soils (including untreated soils) = 0.78

Table 14

Average Effect of Rate of Application of All Liming Materials on Milliequivalents of Exchangeable Magnesium Per 100 Grams of Soil in Greenhouse Experiments

Soil	Rate of Application			Average for Soil
	Untreated	Low	High	
Monmouth loamy sand	0.26	0.60	0.62	0.58
Glenelg loam	1.11	1.14	1.27	1.20
Mattapex silt loam	0.88	1.15	1.32	1.21
Average for Rate	0.75	0.96	1.07	

L.S.D. Soils (including untreated soils) = 0.11

L.S.D. Rates (including untreated soils) = 0.09

L.S.D. Rates (excluding untreated soils) = 0.05

L.S.D. Rates x Soils (including untreated soils) = 0.15

L.S.D. Rates x Soils (excluding untreated soils) = 0.08

Table 15

Average Effect of Rate of Application of All Air Cooled Slag and Limestone Treatments on Soil pH Values in Greenhouse Experiments

Material	Rate of Application			Average for Soil
	Untreated	Low	High	
Air Cooled Slag		5.58	5.88	5.73
Limestone		5.83	6.55	6.19
Average for Rate	5.23	5.71	6.21	

L.S.D. Rates x Materials (excluding untreated soils) = 0.16

L.S.D. Rates x Materials (including untreated soils) = 0.22

Materials not significant when tested with rates x materials interaction.

Rates not significant when tested with rates x materials interaction.

Table 16

Average Effect of Rate of Application of All Air Cooled Slag and Limestone Treatments on Milliequivalents of Exchangeable Hydrogen Per 100 Grams of Soil in Greenhouse Experiments

Material	Rate of Application			Average for Soil
	Untreated	Low	High	
Air Cooled Slag		3.26	2.42	2.84
Limestone		2.67	1.27	1.97
Average for Rate	4.15	2.96	1.84	

L.S.D. Materials (excluding untreated soils) = 0.17

L.S.D. Rates (including untreated soils) = 0.33

L.S.D. Rates x Materials (including untreated soils) = 0.35

L.S.D. Rates x Materials (excluding untreated soils) = 0.25

Table 17

Average Effect of Rate of Application of All Air Cooled Slag and Limestone Treatments on Milliequivalents of Exchangeable Calcium Per 100 Grams of Soil in Greenhouse Experiments

Material	Rate of Application			Average for Soil
	Untreated	Low	High	
Air Cooled Slag		6.38	7.09	6.74
Limestone		7.22	10.11	8.69
Average for Rate	5.58	6.82	8.60	

L.S.D. Materials (excluding untreated soils) = 1.08

L.S.D. Rates (including untreated soils) = 2.87

L.S.D. Rates (excluding untreated soils) = 1.08

Rates x Materials not significant when tested with size x rate x material interaction.

Table 18

Average Effect of Rate of Application of All Air Cooled Slag and Limestone Treatments on Milliequivalents of Exchangeable Magnesium Per 100 Grams of Soil in Greenhouse Experiments

Materials	Rate of Application			Average for Soil
	Untreated	Low	High	
Air Cooled Slag		1.02	1.23	1.12
Limestone		0.91	0.91	0.91
Average for Rate	0.75	0.96	1.07	

L.S.D. Materials (excluding untreated soils) = 0.09

L.S.D. Rates (including untreated soils) = 0.09

L.S.D. Rates (excluding untreated soils) = 0.05

L.S.D. Rates x Materials (including untreated soils) = 0.09

L.S.D. Rates x Materials (excluding untreated soils) = 0.07

Table 19

Average Effect of Rate of Application of All Air Cooled Slag Treatments on Soil pH Values in Field Experiments

Location	Rate of Application			Average for Location
	Untreated	Low	High	
Mattapex silt loam	4.62	4.80	4.98	4.85
Matawan sandy loam (Salisbury)	5.92	6.32	6.45	6.31
Matawan sandy loam (Cordova)	5.08	5.40	5.81	5.53
Sassafras silt loam	5.26	5.62	6.00	5.73
Chester silt loam	5.97	6.53	6.79	6.56
Average for Rate	5.37	5.73	6.01	

L.S.D. Rates (excluding untreated soils) = 0.10

L.S.D. Rates (including untreated soils) = 0.14

L.S.D. Locations (including untreated soils) = 0.14

Locations x Rates interaction could not be calculated because locations were treated as replicates.

Table 20

Average Effect of Rate of Application of All Air Cooled Slag Treatments on Milliequivalents of Exchangeable Hydrogen Per 100 Grams of Soil in Field Experiments

Location	Rate of Application			Average for Location
	Untreated	Low	High	
Mattapex silt loam	6.22	5.00	4.28	4.79
Matawan sandy loam (Salisbury)	2.16	2.07	2.07	2.06
Matawan sandy loam (Cordova)	2.39	2.09	2.13	2.13
Sassafras silt loam	2.42	1.28	1.00	1.26
Chester silt loam	6.13	4.95	3.84	4.55
Average for Rate	3.86	3.08	2.66	

L.S.D. Rates (excluding untreated soils) = 0.32

L.S.D. Rates (including untreated soils) = 0.55

L.S.D. Locations (including untreated soils) = 0.48

Rates x locations interaction could not be calculated because locations were treated as replicates.

Table 21

Average Effect of Rate of Application of All Air Cooled Slag Treatments on Milliequivalents of Exchangeable Calcium Per 100 Grams of Soil in Field Experiments

Location	Rate of Application			Average for Location
	Untreated	Low	High	
Mattapex silt loam	2.61	3.31	3.56	3.36
Matawan sandy loam (Salisbury)	1.52	2.22	1.68	1.91
Matawan sandy loam (Cordova)	2.53	2.74	3.46	3.05
Sassafras silt loam	4.08	4.98	5.27	5.03
Chester silt loam	7.47	7.85	9.32	8.48
Average for Rate	3.64	4.22	4.66	

L.S.D. Rates (excluding untreated soils) = 0.38

L.S.D. Rates (including untreated soils) = 0.52

L.S.D. Locations (including untreated soils) = 0.66

Rates x Locations interaction could not be calculated because locations were treated as replicates.

Table 22

Average Effect of Rate of Application of All Air Cooled Slag Treatments on Milliequivalents of Exchangeable Magnesium Per 100 Grams of Soil in Field Experiments

Location	Rate of Application			Average for Location
	Untreated	Low	High	
Mattapex silt loam	0.59	0.33	0.77	0.55
Matawan sandy loam (Salisbury)	0.86	0.98	0.47	0.74
Matawan sandy loam (Cordova)	0.51	0.59	0.93	0.73
Sassafras silt loam	0.86	1.14	1.18	1.13
Chester silt loam	0.90	1.02	1.52	1.23
Average for Rate	0.74	0.81	0.97	

L.S.D. Locations (including untreated soils) = 0.29

Rates of Application not significant.

Rates x Locations interaction could not be calculated because locations were treated as replicates.

Effect of Fineness

Tables 23, 24, 27 and 28 present the effect of fineness of combined liming materials on pH values and exchangeable cations in soils used in greenhouse tests. When combined in this manner, the averages for fineness show that the 50-60 mesh material has been approximately two to two and one half times as effective as the 10-20 mesh material. The 10-20 mesh material has had a comparatively small effect. The 80-100 mesh material produced greater changes than the 50-60 mesh size.

Tables 25 to 28 inclusive compare the separate effects of fineness of slag and of limestone on pH and exchangeable cations. A study of Table 25 will show that 10-20 mesh slag, 50-60 mesh slag, and 80-100 mesh slag were, respectively, 42, 45, and 66 per cent as effective as limestone of equal fineness in changing soil pH.

A similar relation holds true for exchangeable hydrogen (Table 26). The 10-20 and the 50-60 mesh slags were about 50 per cent as effective, and the 80-100 mesh slag was 68 per cent as effective as limestone of the same fineness in reducing exchangeable hydrogen.

Table 27 shows that the two coarser grades of slag were approximately 35 per cent as effective as limestone in increasing exchangeable calcium, while the 80-100 mesh material was 41 per cent as effective.

Table 28 shows that slag was about twice as effective as limestone in producing an increase in exchangeable magnesium in the two coarser grades. The 80-100 mesh slag was two and one half times as effective. Although slag was more effective in this case, the greatest average increase produced was only 0.31 m.e.

A comparison of the various grades of fineness of slag shows, in Table 25, that 10-20 mesh slag was only 20 per cent as effective as 80-100 mesh slag in changing pH, while 50-60 mesh slag was 60 per cent as effective as the finer slag. For hydrogen and calcium determination (Tables 26, 27), the 10-20 mesh size was about 35 per cent as effective and the 50-60 mesh size about 78 per cent as effective as 80-100 mesh slag.

As far as limestone is concerned, the 10-20 mesh grade was only 30 to 45 per cent as effective as 80-100 mesh limestone in changing pH, exchangeable calcium, and exchangeable hydrogen. The 50-60 mesh grade of limestone was approximately 90 per cent as effective as 80-100 mesh limestone in all tests. Even though the 10-20 mesh limestone was relatively inefficient, it was nearly two and one half times as effective as the same grade of slag.

Table 29 presents the effect of fineness of air cooled slag on soil pH in field experiments. In these experiments the coarse slag was effective in changing the pH and was nearly as effective as the medium grade. The fine slag was no more effective than the medium grade. The effectiveness of two coarser grades is due to the fact that at least 50 per cent of the particles of these two grades will pass a 20 mesh screen. The fine grade of slag would be expected to have more effect than is shown here. It is possible that the finer material may have raised the pH to near the neutral point rather rapidly. The presence of basic ions near neutrality may have inhibited further solution of the slag and may thus have prevented further large increases in pH.

An analysis was carried out to determine the effect of fineness of air cooled slag at low and high rates of application on soil pH in field experiments. Fineness had no significant effect at the low rate of application but was significant at the high rate. It is suggested that differences in total amounts of the various size fractions within the coarse, medium and fine groups were not great enough at the low rate of application to produce significant pH changes. Actually, the greatest average increase in pH at the low rate of application was 0.4 pH unit.

Table 23

Average Effect of Fineness of All Liming Materials on Soil pH Values in Greenhouse Experiments

Soil	Untreated	Fineness			Average for Soil
		10-20 mesh	50-60 mesh	80-100 mesh	
Monmouth loamy sand	4.96	5.61	6.20	6.57	6.04
Glenelg loam	6.28	6.35	6.60	6.71	6.53
Mattapex silt loam	4.46	4.74	5.34	5.54	5.15
Average for fineness	5.23	5.56	6.05	6.27	

L.S.D. Fineness (excluding untreated soils) = 0.36

L.S.D. Soils (including untreated soils) = 0.47

L.S.D. Fineness x soil (excluding untreated soils) = 0.24

Table 24

Average Effect of Fineness of All Liming Materials on Milliequivalents of Exchangeable Hydrogen Per 100 Grams of Soil In Greenhouse Experiments

Soil	Untreated	Fineness			Average for Soil
		10-20 mesh	50-60 mesh	80-100 mesh	
Monmouth loamy sand	3.20	1.52	1.10	0.76	1.29
Glenelg loam	1.84	1.52	0.83	0.71	1.08
Mattapex silt loam	7.41	6.53	4.53	4.12	5.24
Average for fineness	4.15	3.19	2.15	1.86	

L.S.D. Soils (excluding untreated soils) = 0.21

L.S.D. Fineness (excluding untreated soils) = 0.21

L.S.D. Fineness x soils (excluding untreated soils) = 0.37

Table 25

Average Effect of Fineness of Air Cooled Slag and Limestone on Soil pH Values in Greenhouse Experiments

Material	Untreated	Fineness 10-20 mesh	50-60 mesh	80-100 mesh	Average for Material
Air cooled slag		5.40	5.73	6.06	5.73
Limestone		5.73	6.36	6.49	6.19
Average for fineness	5.23	5.56	6.05	6.27	

L.S.D. Fineness (excluding untreated soils) = 0.36

Materials not significant when tested with rates x materials interaction.

Fineness x materials not significant when tested with pooled three and four factor interactions.

Table 26

Average Effect of Fineness of Air Cooled Slag and Limestone on Milliequivalents of Exchangeable Hydrogen Per 100 Grams of Soil in Greenhouse Experiments

Material	Untreated	Fineness			Average for Material
		10-20 mesh	50-60 mesh	80-100 mesh	
Air cooled slag		3.46	2.71	2.34	2.84
Limestone		2.92	1.59	1.39	1.97
Average for fineness	4.15	3.19	2.15	1.86	

L.S.D. Materials (excluding untreated soils) = 0.17

L.S.D. Fineness (excluding untreated soils) = 0.21

L.S.D. Fineness x Materials (excluding untreated soils) = 0.30

Table 27

Average Effect of Fineness of Air Cooled Slag and Limestone on Milliequivalents of Exchangeable Calcium Per 100 Grams of Soil In Greenhouse Experiments

Material	Untreated	Fineness 10-20 mesh	Fineness 50-60 mesh	Fineness 80-100 mesh	Average for Material
Air cooled slag		6.13	6.84	7.24	6.74
Limestone		7.08	9.31	9.67	8.69
Average for fineness	5.58	6.60	8.07	8.45	

L.S.D. Materials (excluding untreated soils) = 1.08

L.S.D. Fineness (excluding untreated soils) = 1.88

Fineness x materials not significant when tested with fineness x rate x material interaction.

Table 28

Average Effect of Fineness of Air Cooled Slag and Limestone on Milliequivalents of Exchangeable Magnesium Per 100 Grams Of Soil In Greenhouse Experiments

Material	Untreated	Fineness 10-20 mesh	Fineness 50-60 mesh	Fineness 80-100 mesh	Average for Material
Air cooled slag		0.95	1.16	1.25	1.12
Limestone		0.87	0.92	0.94	0.91
Average for fineness	0.75	0.91	1.04	1.10	

L.S.D. Materials (excluding untreated soils) = 0.09

L.S.D. Fineness (excluding untreated soils) = 0.11

L.S.D. Fineness x Materials not significant when tested with fineness x soil x material interaction.

Table 29

Average Effect of Fineness of Air Cooled Slag on Soil pH Values in Field Experiments

Location	Untreated Plots	Fineness Slag Passing 100 Mesh Screen Per Cent			Average for Location
		14.6 Coarse	50.6 Medium	99.3 Fine	
Mattapex silt loam	4.62	4.79	4.90	5.00	4.85
Matawan sandy loam (Salisbury)	5.92	6.30	6.45	6.39	6.31
Matawan sandy loam (Cordova)	5.08	5.40	5.75	5.70	5.53
Sassafras silt loam	5.26	5.73	5.67	5.83	5.73
Chester silt loam	5.97	6.56	6.71	6.71	6.56
Average for fineness	5.37	5.76	5.94	5.92	

L.S.D. Locations (including untreated soils) = 0.14

L.S.D. Fineness (including untreated soils) = 0.15

L.S.D. Fineness (excluding untreated soils) = 0.12

Fineness x location interaction could not be calculated because locations were treated as replicates.

Effect of Time

Since soil pH values were not significantly different at the various sampling dates in either greenhouse or field experiments, the greatest change in pH must have occurred soon after treatment.

Table 30 shows that pH values at ten months and fourteen months were not significantly different in greenhouse experiments when the dates x soils interaction was used as a test of significance. This result was not expected, because it was thought that increased reaction time for liming materials in the soil should produce further increases in pH. On the Monmouth soil, pH values for treated soils were practically the same at ten and fourteen months, while pH values increased considerably at the second sampling date on Glenelg and Mattapex soils. Untreated Monmouth soil decreased in pH from the ten month sampling date to the fourteen month date, but the untreated Glenelg and Mattapex soils showed marked increases in pH. Thus, the failure to obtain significant differences in pH values appears to be due to the wide variations in pH at different sampling dates on the three soils tested.

The increase of nearly 0.9 pH unit in four months on untreated Glenelg soil is difficult to explain. Since pH measurements were rechecked in this case and were found to be correct, error in data can be ruled out. As a possible explanation it is suggested that there may have been undissolved limestone or calcium carbonate in this soil which went into solution after the ten month sampling date. Contamination of the soil is another possible source of error, but does not seem to be probable because pH values for duplicate pots were almost identical. Since neither explanation is entirely satisfactory, further work should be carried out to determine the reason for this increase in pH.

Tables 33 and 34 present the relation between sampling dates and pH values in field tests. Here again, dates were not significantly different because of the large dates x location interaction. The dates x rates and dates x fineness interactions were also not significant.

As previously indicated, the greatest change in soil reaction probably occurred within the first two to four months after application. Hoyert (16), in work on the same field plots as used in this experiment, showed that limestone treatments also produced the greatest increases in soil pH within two to four months after application. These observations help to further explain the failure to obtain significant differences in pH between the ten and fourteen month sampling dates in greenhouse experiments.

Table 30

Average Effect of Sampling Date on pH Values of Soils Treated with Air Cooled Slag and Limestone in Greenhouse Experiments

Soil	Treatment	Sampling Date		Average for Soil
		10 Months	14 Months	
Monmouth loamy sand	Untreated	5.07	4.84	4.96
	Treated	6.11	6.14	6.13
Glenelg loam	Untreated	5.88	6.77	6.26
	Treated	6.16	6.95	6.56
Nattapex silt loam	Untreated	4.25	4.68	4.46
	Treated	4.83	5.58	5.21
Average for Date (Excluding untreated soils)	Untreated	5.07	5.40	
	Treated	5.70	6.22	

L.S.D. Soils (excluding untreated soils) = 0.53

L.S.D. Dates x soils (excluding untreated soils) = 0.06

Dates not significant when tested with dates x soils interaction.

Table 31

Average Effect of Sampling Date on pH Values of Soils Treated with Air Cooled Slag and Limestone in Greenhouse Experiments

Material	Sampling Date		Average for Material
	10 Months	14 Months	
Untreated	5.07	5.40	5.23
Air cooled slag	5.49	5.97	5.73
Limestone	5.91	6.47	6.19
Average for Date (excluding untreated soils)	5.70	6.22	

L.S.D. Dates x Materials (excluding untreated soils) = 0.05

Dates not significant when tested with dates x soils interaction.

Materials not significant when tested with rates x materials interaction.

Table 32

Average Effect of Sampling Date on pH Values of Soils Treated With All Liming Materials at Different Rates of Application in Greenhouse Experiments

Rate of Application	Sampling Date		Average for Rate
	10 Months	14 Months	
Untreated	5.07	5.40	5.23
Low	5.48	5.94	5.71
High	5.93	6.50	6.21
Average for Date (excluding untreated soils)	5.70	6.22	

L.S.D. Rates x Dates (excluding untreated soils) = 0.05

Dates not significant when tested with dates x soils interaction.

Rates not significant when tested with rates x materials interaction.

Table 33

Average Effect of Sampling Date on pH Values of Soils Treated With Air Cooled Slag in Field Experiments

Location	Sampling Date				Average for Location
	2 Mo.	1 Yr.	2 Yrs.	3 Yrs.	
Mattapex silt loam	4.61	4.92	4.90	4.97	4.85
Matawan sandy loam (Salisbury)	6.25	5.97	6.40	6.64	6.31
Matawan sandy loam (Cordova)	5.62	5.85	5.58	5.08	5.53
Sassafras silt loam	5.70	5.86	5.79	5.60	5.73
Chester silt loam	6.21	6.47	6.70	6.87	6.56
Average for Sampling Date	5.68	5.81	5.87	5.82	

L.S.D. Locations (including untreated plots) = 0.14

L.S.D. Dates x location (including untreated plots) = 0.23

Dates not significant when tested with dates x location interaction.

Table 34

Average Effect of Sampling Date at Different Rates of Application of Air Cooled Slag on Soil pH Values in Field Experiments

Location	Relative Rate of Application	Sampling Date 2 Mo.	1 Yr.	2 Yrs.	3 Yrs.	Average for Location
Mattapex silt loam	Untreated	4.41	4.76	4.71	4.60	4.62
	Low	4.59	4.86	4.98	4.76	4.79
	High	4.70	5.04	4.87	5.31	4.98
Matawan sandy loam (Salisbury)	Untreated	5.87	5.62	6.05	6.14	5.92
	Low	6.39	5.89	6.31	6.67	6.31
	High	6.22	6.17	6.61	6.79	6.45
Matawan sandy loam (Cordova)	Untreated	5.10	5.56	5.01	4.66	5.08
	Low	5.68	5.71	5.37	4.86	5.40
	High	5.73	6.09	6.33	5.43	5.81
Sassafras silt loam	Untreated	5.12	5.58	5.14	5.18	5.26
	Low	5.66	5.86	5.49	5.46	5.62
	High	5.94	5.96	6.24	5.87	6.00
Chester silt loam	Untreated	5.80	5.90	6.02	6.18	5.98
	Low	6.20	6.38	6.65	6.90	6.53
	High	6.36	6.74	6.98	7.09	6.79
Average for Sampling Date	Untreated	5.26	5.48	5.39	5.35	
	Low	5.71	5.74	5.76	5.73	
	High	5.79	6.00	6.14	6.10	

L.S.D. Dates x Location - Low Rate (excluding untreated plots) = 0.30
L.S.D. Dates x Location - High Rate (excluding untreated plots) = 0.44
L.S.D. Locations - Low Rate (excluding untreated plots) = 0.49
L.S.D. Locations - High Rate (excluding untreated plots) = 0.38
Dates not significant at medium or heavy rate.

Crop Yields

It has previously been stated that yield data for field tests in this series of experiments could not be statistically analyzed because field plots were not randomized. For this reason and because individual plot yields varied widely, it is not possible to make positive statements concerning the effect of slag on crop yields. When it is considered, however, that plots were replicated four times and yields were taken over a three year period, trends in the yield data may be pointed out which should provide a basis for limited conclusions.

Corn

Table 35 presents the relative effect of air cooled slag on corn yields as composited for all tests. It can be seen that air cooled slag had ver little effect on yields two months after application and two years after application. Air cooled slag one year after application seems to have increased corn yields, but the results are variable.

Table 36 shows that granulated manganese slag, one year after application, had a considerable effect in increasing corn yields. However, these results were obtained at only one location. At that location the manganese slag plots were by chance located in slightly lower parts of the field and may have received more moisture than other plots. While these facts tend to minimize the yield increases, it must also be remembered that a considerable part of the response on Matawan sandy loam soil may have been due to manganese added by this type of slag. Certainly this would merit further investigation.

Table 37 shows that foamed slag had no more effect on corn yields than did air cooled slag.

In Tables 44, 45, and 46 the relative values for all three years of the tests have been composited. These summaries minimize the effects in any one year and show that all forms of slag have only produced small increases in yields of corn.

Table 35

The Relative Effect of Air Cooled Slag on Corn Yields as Composited For All Tests*
In Field Experiments

Treatment	Slag Passing 100 Mesh Screen Per Cent	Relative Amount Applied	Relative Values Composited by Period**					
			After 2 Months		After 1 Year		After 2 Years	
			No. of Tests	Relative Value	No. of Tests	Relative Value	No. of Tests	Relative Value
Air Cooled Slag	14.6	Low	3	103	2	122	1	97
Air Cooled Slag	14.6	High	3	105	3	94	1	88
Air Cooled Slag	27.5	Low	3	103	2	105	1	92
Air Cooled Slag	27.5	High	3	105	3	102	1	99
Air Cooled Slag	50.6	Low	3	100	2	118	1	100
Air Cooled Slag	50.6	High	3	97	3	111	1	96
Air Cooled Slag	79.4	Low	3	106	2	108	1	99
Air Cooled Slag	79.4	High	3	106	3	120	1	113
Air Cooled Slag	99.3	Low	3	104	2	95	1	91
Air Cooled Slag	99.3	High	3	104	3	126	1	85
Untreated		None	3	100	2 or 3	100	1	100

*The word test refers to location. In each test there were four replicates.

**Relative Value Composited = $\frac{\text{Sum of average yields per treatment in each test}}{\text{Sum of average yields of untreated plots in each test}} \times 100$

Table 36

The Relative Effect of Granulated Manganese Slag on Corn Yields as Composited For All Tests* in Field Experiments

Treatment	Slag Passing 100 Mesh Screen	Relative Amount Applied	Relative Values Composited by Period**					
			After 2 Months		After 1 Year		After 2 Years	
	Per Cent		No. of Tests	Relative Value	No. of Tests	Relative Value	No. of Tests	Relative Value
Granulated Manganese Slag	16.3	Low	1	99	1	157	1	91
Granulated Manganese Slag	16.3	High	1	106	1	178	1	79
Granulated Manganese Slag	27.0	Low	1	102	1	132	1	97
Granulated Manganese Slag	27.0	High	1	—	1	133	1	99
Granulated Manganese Slag	77.8	Low	1	96	1	171	1	102
Granulated Manganese Slag	77.8	High	—	—	1	179	1	98
Untreated		None	1	100	1	100	1	100

*The word test refers to location. In each test there were four replicates.

$$\text{**Relative Value Composited} = \frac{\text{Sum of average yields per treatment in each test}}{\text{Sum of average yields of untreated plots in each test}} \times 100$$

Table 37

The Relative Effect of Foamed Slag on Corn Yields as Composited for All Tests* in Field Experiments

Treatment	Slag Passing 100 Mesh Screen Per Cent	Relative Amount Applied	Relative Values Composited by Period **	
			After 2 Months	
			No. of Tests	Relative Value
Foamed Slag	27.0	Low	3	103
Foamed Slag	27.0	High	3	106
Foamed Slag	76.3	Low	3	106
Foamed Slag	76.3	High	3	108
Untreated		None	3	100

*The word test refers to location. In each test there were four replicates.

**Relative Value Composited = $\frac{\text{Sum of average yields per treatment in each test}}{\text{Sum of average yields on untreated plots in each test}} \times 100$

Wheat and Barley

Tables 38, 39 and 40 summarize the effects of slag treatments on small grains. Air cooled slag and foamed slag produced consistent increases in yields of straw. Granulated manganese slag had little effect on straw yields.

All forms of slag appear to have increased grain yields even two years after application. These trends are more clearly shown when the data for separate years is composited into one set of data - Tables 44, 45 and 46. Greatest increases of grain have been produced by the heavy rates of application. Increases in grain yields also appear to be correlated with increases in fineness of air cooled slag up to the point where 50.6 per cent of slag passes a 100 mesh screen. Increasing fineness above this point does not seem to increase the effectiveness of the slag.

The Relative Effect of Air Cooled Slag on Yields of Wheat and Barley as Composited for all Tests*
in Field Experiments

Treatment	Slag Passing 100 Mesh Screen per cent	Relative Amount Applied	Relative Values Composited by Period**											
			Straw						Grain					
			After 2 mos.		After 1yr.		after 2 yrs		After 2 mos		After 1 yr		After 2 yrs	
			No. of Tests	Relative Value	No. of Tests	Relative Value	No. of Tests	Relative Value	No. of Tests	Relative Value	No. of Tests	Relative Value	No. of Tests	Relative Value
Air Cooled Slag	14.6	Low	1	90	3	103	2	108	1	113	3	92	2	111
Air Cooled Slag	14.6	High	1	114	3	113	4	103	1	124	3	102	4	108
Air Cooled Slag	27.5	Low	1	93	3	100	2	107	1	129	3	92	2	118
Air Cooled Slag	27.5	High	1	131	3	122	4	109	1	123	3	108	4	112
Air Cooled Slag	50.6	Low	1	103	3	116	2	115	1	103	3	102	2	113
Air Cooled Slag	50.6	High	1	81	3	128	4	114	1	108	3	116	4	121
Air Cooled Slag	79.4	Low	1	108	3	117	2	110	1	82	3	105	2	111
Air Cooled Slag	79.4	High	1	90	3	128	4	111	1	95	3	122	4	115
Air Cooled Slag	99.3	Low	1	111	3	117	2	112	1	102	3	104	2	112
Air Cooled Slag	99.3	High	1	93	3	122	4	109	1	105	3	117	4	122
Untreated		None	1	100	3	100	2 or 4	100	1	100	3	100	2 or 4	

* The word test refers to location. In each test there were four replicates.

** Relative Value Composited by period $= \frac{\text{Sum of Average yields per treatment in each test}}{\text{Sum of average yields of untreated plots in each test}} \times 100$

Table 39

The Relative Effect of Granulated Manganese Slag on Yields of Wheat and Barley As Composited for all Tests* in Field Experiments

Treatment	Slag Passing 100 Mesh Screen Per Cent	Relative Amount Applied	Relative Values Composited by Period**							
			Straw				Grain			
			After 1 Year		After 2 Years		After 1 Year		After 2 Years	
			No. of Tests	Relative Value	No. of Tests	Relative Value	No. of Tests	Relative Value	No. of Tests	Relative Value
Granulated Manganese Slag	16.3	Low	1	97	1	98	1	99	1	97
Granulated Manganese Slag	16.3	High	1	102	1	101	1	106	1	100
Granulated Manganese Slag	27.0	Low	1	108	1	92	1	110	1	129
Granulated Manganese Slag	27.0	High	1	115	1	112	1	114	1	107
Granulated Manganese Slag	77.8	Low	1	98	1	93	1	97	1	96
Granulated Manganese Slag	77.8	High	1	105	1	105	1	113	1	98
Untreated		None	1	100	1	100	1	100	1	100

*The word test refers to location. In each test there were four replicates.

$$\text{**Relative Value Composited} = \frac{\text{Sum of average yields per treatment in each test}}{\text{Sum of average yields of untreated plots in each test}} \times 100$$

Table 40

The Relative Effect of Foamed Slag on Yields of Wheat and Barley as Composited for all Tests* in Field Experiments

Treatment	Slag Passing 100 Mesh Screen Per Cent	Relative Amount Applied	Relative Values Composited by Period**							
			Straw				Grain			
			After 1 Year		After 2 Years		After 1 Year		After 2 Years	
			No. of Tests	Relative Value	No. of Tests	Relative Value	No. of Tests	Relative Value	No. of Tests	Relative Value
Foamed Slag	27.0	Low	3	117	1	103	3	110	1	113
Foamed Slag	27.0	High	3	124	1	87	3	124	1	100
Foamed Slag	76.3	Low	3	115	1	107	3	110	1	110
Foamed Slag	76.3	High	3	123	1	99	3	125	1	108
Untreated		None	3	100	1	100	3	100	1	100

*The word test refers to location. In each test there were four replicates.

$$\text{**Relative Value Composited} = \frac{\text{Sum of average yields per treatment in each test}}{\text{Sum of average yields of untreated plots in each test}} \times 100$$

Clover and Timothy Hay

Air cooled slag appears to have been more effective in increasing hay yields than in increasing yields of corn or wheat. The greatest increase in hay yields (see Table 41) was obtained one year after air cooled slag was applied. Increasing the rate of application and fineness of grinding of slag has tended to increase yields in this one year. Results obtained two months after application and two years after application were so highly variable that no conclusions can be drawn.

While granulated manganese slag (Table 42) seems to have had considerable effect on hay yields on Matawan sandy loam soil, this effect must be minimized because these plots may have received more moisture as they happened to be located at slightly lower parts of the field (see page 66).

Hay was not grown on foamed slag plots in 1947 and 1948. Yields of hay in 1949 (Table 43) show no response to foamed slag treatments.

Data for the three crop years on air cooled slag plots are composited in Table 44. This table shows that the yield response over the three year period was varied.

In work on these same plots, Hoyert (16) reported similar increases in hay yields one year after application of pulverized limestone. He also noted the similar increase in yields of wheat straw from limestone treatments as was reported for slag treatments (page 7).

Alfalfa Hay

Response of alfalfa hay to slag and limestone treatments on Monmouth loamy sand soil is presented in Table 47. Since slag and limestone materials were not of the same degrees of fineness, it is difficult to compare very closely the effects of the two materials.

Yields of alfalfa hay for this experiment may seem exceptionally

Table 42

The Relative Effect of Air Cooled Slag on Yields of Clover and Timothy Hay as Composited for all Tests* in Field Experiments

Treatment	Slag Passing 100 Mesh Screen Per Cent	Relative Amount Applied	Relative Values Composited by Period**					
			After 2 Months		After 1 Year		After 2 Years	
			No. of Tests	Relative Value	No. of Tests	Relative Value	No. of Tests	Relative Value
Air Cooled Slag	14.6	Low	1	140	1	250	1	96
Air Cooled Slag	14.6	High	3	100	1	304	1	89
Air Cooled Slag	27.5	Low	1	160	1	259	1	103
Air Cooled Slag	27.5	High	3	99	1	246	1	102
Air Cooled Slag	50.6	Low	1	180	1	268	1	99
Air Cooled Slag	50.6	High	3	82	1	278	1	99
Air Cooled Slag	79.4	Low	1	160	1	309	1	96
Air Cooled Slag	79.4	High	3	92	1	327	1	90
Air Cooled Slag	99.3	Low	1	140	1	300	1	87
Air Cooled Slag	99.3	High	3	95	1	346	1	100
Untreated		None	1 or 3	100	1	100	1	100

*The word test refers to location. In each test there were four replicates.

**Relative Value Composited = $\frac{\text{Sum of average yields per treatment in each test}}{\text{Sum of average yields of untreated plots in each test}} \times 100$

Table 42

The Relative Effect of Granulated Manganese Slag on Yields of Clover and Timothy Hay as Composited for all Tests* in Field Experiments

Treatment	Slag Passing 100 Mesh Screen Per Cent	Relative Amount Applied	Relative Values Composited by Period** After 2 Months: No. of Tests	Relative Values Composited by Period** After 2 Months: Relative Value
Granulated Manganese Slag	16.3	Low	1	140
Granulated Manganese Slag	16.3	High	1	140
Granulated Manganese Slag	27.0	Low	1	200
Granulated Manganese Slag	27.0	High	1	180
Granulated Manganese Slag	77.8	Low	1	200
Granulated Manganese Slag	77.8	High	1	220
Untreated		None	1	100

*The word test refers to location. In each test there were four replicates.

**Relative Value Composited = $\frac{\text{Sum of average yields per treatment in each plot}}{\text{Sum of average yields of untreated plots in each test}} \times 100$

Table 43

The Relative Effect of Foamed Slag on Yields of Clover and Timothy Hay as Composited for all Tests* in Field Experiments

Treatment	Slag Passing 100 Mesh Screen Per Cent	Relative Amount Applied	Relative Values Composited by Period**	
			After 2 Years	
			No. of Tests	Relative Value
Foamed Slag	27.0	Low	1	90
Foamed Slag	27.0	High	1	104
Foamed Slag	76.3	Low	1	86
Foamed Slag	76.3	High	1	86
Untreated		None	1	100

*The word test refers to location. In each test there were four replicates.

$$\text{**Relative Value Composited} = \frac{\text{Sum of average yields per treatment in each test}}{\text{Sum of average yields of untreated plots in each test}} \times 100$$

Table 44

The Relative Effect of Air Cooled Slag on Yields of Clover and Timothy Hay, Small Grain and Corn for the Combined Years of 1947, 1948, 1949 in Field Experiments

Treatment	Slag Passing 100 Mesh Screen	Relative Amount Applied	Overall Composited Relative Values*							
			Hay		Wheat and Barley				Corn	
					Straw		Grain			
	Per Cent		No. of Tests **	Relative Value	No. of Tests	Relative Value	No. of Tests	Relative Value	No. of Tests	Relative Value
Air Cooled Slag	14.6	Low	3	116	6	104	6	102	6	106
Air Cooled Slag	14.6	High	5	105	8	107	8	107	7	100
Air Cooled Slag	27.5	Low	3	125	6	102	6	103	6	102
Air Cooled Slag	27.5	High	5	106	8	115	8	111	7	104
Air Cooled Slag	50.6	Low	3	127	6	114	6	107	6	104
Air Cooled Slag	50.6	High	5	97	8	116	8	118	7	100
Air Cooled Slag	79.4	Low	3	124	6	113	6	105	6	105
Air Cooled Slag	79.4	High	5	102	8	115	8	117	7	110
Air Cooled Slag	99.3	Low	3	114	6	114	6	108	6	101
Air Cooled Slag	99.3	High	5	108	8	112	8	119	7	108
Untreated		None	3 or 5	100	6 or 8	100	6 or 8	100	6 or 7	100

*Overall Composited Relative Value = $\frac{\text{Sum of average yields per treatment for each test and all periods}}{\text{Sum of average yields of untreated plots for each test and all perpds}}$

**In each test there were four replicates.

Table 45

The Relative Effect of Granulated Manganese Slag on Yields of Clover and Timothy Hay, Small Grain, and Corn for the Combined Years of 1947, 1948, 1949 in Field Experiments

Treatment	Slag Passing 100 Mesh Screen per cent	Relative Amount Applied	Overall Composited Relative Values*							
			Hay		Wheat and Barley				Corn	
					Straw		Grain			
			No. of Tests	Relative Value	No. of Tests	Relative Value	No. of Tests	Relative Value	No. of Tests	Relative Value
Granulated Manganese Slag	16.3	Low	1	140	2	98	2	98	3	105
Granulated Manganese Slag	16.3	High	1	140	2	101	2	103	3	108
Granulated Manganese Slag	27.0	Low	1	200	2	99	2	120	3	105
Granulated Manganese Slag	27.0	High	1	180	2	113	2	110	2	110
Granulated Manganese Slag	77.8	Low	1	200	2	95	2	96	3	109
Granulated Manganese Slag	77.8	High	1	220	2	105	2	103	2	124
Untreated		None	1	100	2	100	2	100	2 or 3	100

* Overall Composited Relative Value = $\frac{\text{Sum of average yields per treatment for each test and all periods}}{\text{Sum of average yields of untreated plots for each test and all periods}}$

** In each test there were four replicates

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Table 46

The Relative Effect of Foamed Slag on Yields of Clover and Timothy Hay, Small Grain, and Corn for the Combined Years of 1947, 1948, 1949 in Field Experiments

Treatment	Slag Passing 100 Mesh Screen	Relative Amount Applied	Overall Composited Relative Values*							
			Hay		Wheat and Barley				Corn	
					Straw		Grain			
	per cent		No. of Tests	Relative Value	No. of Tests	Relative Value	No. of Tests	Relative Value	No. of Tests	Relative Value
Foamed Slag	27.0	Low	1	90	4	111	4	111	3	103
Foamed Slag	27.0	High	1	104	4	109	4	116	3	106
Foamed Slag	76.3	Low	1	86	4	112	4	110	3	106
Foamed Slag	76.3	High	1	100	4	114	4	119	3	108
Untreated		None	1	100	4	100	4	100	3	100

* Overall Composited Relative Value = Sum of average yields per treatment for each test and all periods / Sum of average yields of untreated plots for each test and all periods

** In each test there were four replicates large because of the fact that results were calculated in terms of hay at 20 per cent moisture content. Hay yields are more often calculated at 15 per cent moisture.

It can be seen that both slag and limestone produced substantial increases in growth of alfalfa. However, during the first harvest year, slag plots had a noticeably poorer stand of alfalfa and were estimated to contain 30 to 40 per cent weeds, while limestone plots contained an estimated 10 per cent weeds.

All plots were reseeded between the first and second harvest years. During the second harvest season the difference in stand between plots treated with slag and those treated with limestone was less noticeable. Slag plots were estimated to contain 20 to 25 per cent weeds and limestone plots 10 per cent.

In the third harvest year there was little noticeable difference in stand between slag and limestone plots. Slag plots contained 10 to 15 per cent weeds and limestone plots 10 per cent weeds (estimated values).

During each of the three harvest years the percentage of weeds in untreated plots increased. At the end of the third year untreated plots contained 52 per cent (by weight) of weeds.

Results indicate that air cooled slag can be used in the production of alfalfa, but that it is not as effective for the first two years after application as pulverized limestone of comparable fineness and equivalent amounts. On an acid soil it would, therefore, be necessary to apply slag one or two years in advance of seeding alfalfa or to apply large quantities of slag in order to prevent reduction in stand and obtain good production.

These observations are not in agreement with the work of Carter et al (10) who reported that in most cases slag was as efficient in crop production as limestone of similar fineness if applied in equivalent amounts.

Table 47

Response of Alfalfa Hay to Slag and Limestone Treatments on Monmouth Loamy Sand Soil in Field Experiments

	Liming Material Passing 100 Mesh Screen per cent	Liming Material Tons/ acre	Alfalfa Hay 1 year after Treatment* Tons/ acre	Relative Value	2 years after Treatment* Tons/ acre	Relative Value	3 years after Treatment* Tons/ acre	Relative Value	Total Yield	Relative Value
Air Cooled Slag	14.6	1.65	3.61	97	2.41	127	5.03	118	11.05	112
Coarse Limestone	22.6	1.47	4.18	113	2.40	126	4.84	114	11.42	116
Air Cooled Slag	14.6	6.10	4.16	112	2.70	142	5.06	119	11.92	121
Coarse Limestone	22.6	5.54	4.34	117	2.71	142	5.17	122	12.22	124
Air Cooled Slag	50.6	1.65	4.04	1.09	2.57	135	5.24	123	11.85	120
Medium Limestone	27.2	1.47	4.42	119	2.68	141	5.07	120	12.17	123
Air Cooled Slag	50.6	6.10	4.65	145	2.76	145	5.11	121	12.52	127
Medium Limestone	27.2	5.54	4.69	126	2.37	124	4.93	116	11.99	122
Air Cooled Slag	79.4	1.65	3.71	100	2.72	143	4.86	115	11.29	115
Pulverized Lime-stone	77.5	1.47	4.12	111	2.75	145	5.15	122	12.02	122
Air Cooled Slag	79.4	6.10	4.17	113	2.49	131	5.34	126	12.00	122
Pulverized Lime-stone	77.5	5.54	4.18	113	2.54	134	4.84	114	11.56	118
Untreated	—	None	3.70	100	1.90	100	4.24	100	9.84	100

* 2 cuttings per year

DISCUSSION

In order to make practical use of the results of these investigations, it is necessary to consider amounts and fineness of blast furnace slag available in Maryland, rates of application of slag, and relative costs of slag and limestone.

Quantities of Slag Available in Maryland

Approximately 900,000 tons of slag are produced each year in Baltimore. Of this total about 20 per cent, or 180,000 tons, can be converted to agricultural slag by screening. At the present time, however, demands of other industries have reduced stockpiles of slag screenings in Baltimore to approximately 15,000 tons. If the demand for agricultural slag were to increase, the rate of screening could be increased to meet demands of as much as 180,000 tons per year.

Fineness of Slag Available in Maryland

A mechanical analysis of a typical lot of blast furnace slag which is presently available for sale in Maryland for agricultural purposes is listed below:

Table 48

Mechanical Analysis of Maryland Agricultural Slag*

U. S. of S. Screen Number	4	8	10	20	40	80	100	200
Per Cent Passing Above Screen	100	87.0	81.0	48.5	32.5	18.0	14.7	9.0

*Data furnished by the Arundel Corporation, Baltimore, Maryland.

Table 25 shows that 10-20 mesh slag produced an average increase of 0.17 pH, 50-60 mesh slag increased pH by an average of 0.50 pH and 80-100 mesh slag produced an average increase of 0.83 pH for the soils tested. Using these average values, an estimate of the effectiveness of the various particle size groups relative to the 50-60 mesh size can be made by the following calculation:

Effectiveness of 10-20 mesh slag = 0.17/0.50 x 100 = 34%

Effectiveness of 50-60 mesh slag = 0.50/0.50 x 100 = 100%

Effectiveness of 80-100 mesh slag = 0.83/0.50 x 100 = 166%

From these figures it can be estimated that material coarser than 20 mesh has an effectiveness no greater than 15 per cent of the 50-60 mesh slag. The material between 20 and 80 mesh may also be assumed to have an average effectiveness the same as that of 50-60 mesh slag. Material finer than 100 mesh can be given an estimated effectiveness of 175 per cent. Using these values and the values for mechanical analysis of slag sold in Maryland (Table 48), an evaluation of the effectiveness of Maryland agricultural slag can be made relative to the 50-60 mesh group. The percentage figures in Table 48 can be converted to actual grams of the different size separates per 100 grams of slag as follows:

4-10 mesh slag	=	19.0 grams
10-20 mesh slag	=	32.5 grams
20-80 mesh slag	=	30.5 grams
80-100 mesh slag	=	3.3 grams
Slag finer than 100 mesh	=	14.7 grams
Total	=	100.0 grams

Since these separates are of different effectiveness they may be related to 50-60 mesh slag by multiplying the weights of each size group by the proper percentage effectiveness as follows:

$$19.0 \times 0.15 = 2.8 \text{ grams}$$
$$32.5 \times 0.34 = 11.1 \text{ grams}$$
$$30.5 \times 1.00 = 30.5 \text{ grams}$$
$$3.3 \times 1.66 = 5.5 \text{ grams}$$
$$14.7 \times 1.75 = 25.7 \text{ grams}$$

75.6 grams - effective weight of Maryland agricultural slag per 100 grams

Thus, the slag that is sold at present in Maryland is only 75.6 per cent as effective as 50-60 mesh slag.

Data of this experiment indicates that the screening process used in the preparation of agricultural slag should be altered so that all slag offered for sale will pass a 20 mesh screen and a large part will pass a 50 mesh screen. If the agricultural slag shown in Table 45 is screened so that all material coarser than 20 mesh is removed, then the remaining fine screenings will contain 63 per cent of 20-80 mesh slag, 7 per cent of 80-100 mesh slag, and 30 per cent finer than 100 mesh. The effectiveness of this material relative to 50-60 mesh slag is 117 per cent. This slag may now be compared with the agricultural slag of Table 45 to determine the relative effectiveness of these two materials.

$$75.6/117 \times 100 = 64.6\%$$

In other words, Maryland agricultural slag is only 65 per cent (64.6 per cent) as effective as it could be if it were screened to remove material coarser than 20 mesh.

Rates of Application of Slag for Different Soil Classes in Maryland

The discussions of materials (page 28) and rates of application (page 34) show that slag had approximately half the effect of limestone of the same fineness in changing soil pH and exchangeable cations when applied in equivalent amounts. This data and the discussion of fineness (page 51) indicate that it would be necessary to apply slag finer than 20 mesh to the soil in amounts furnishing twice as much total oxides as limestone, in order to have the same effect on soil reaction. If this air cooled slag has an average composition of 45 per cent total oxides, and limestone an average content of 52 per cent, then 2.25 pounds of slag should be as effective as one pound of limestone of similar fineness. Since the agricultural slag now available in Maryland is only 65 per cent as effective as slag with material coarser than 20 mesh removed, then 3.5 pounds of present day agricultural slag will be required to equal one pound of limestone finer than 20 mesh.

On the basis of liming investigations conducted on the same soils included in this experiment and on other Maryland soils, Hoyert (26) developed a lime recommendation table showing the tons of limestone required to change soil of different textures and of different initial pH to pH 6.5. This data has been modified in Table 49 to include both agricultural slag sold in Maryland and a similar slag with material coarser than 20 mesh removed.

The amounts of slag in this table are based entirely upon the effect of slag on soil pH. The recommendations do not take into account other effects of slag on crop yields such as the addition of trace elements, however, it is generally accepted that soils are limed primarily for the purpose of reducing acidity and reducing toxicity of certain elements. If slag is to accomplish this purpose, the data of these experiments indicate that Maryland agricultural slag should be applied in the amount given in Table 49 in order to attain a pH of 6.5.

These statements do not mean that slag will have no effect on

Table 49

Approximate Amounts of Liming Material Recommended for Different Soil Classes in Maryland to Attain a pH of 6.5

pH of Unlimed Soil	Tons of Liming Material Recommended per Acre								
	Sandy Loams			Silt Loams			Silty Clay Loams		
	Pulverized Limestone	Air Cooled Slag Finer Than 20 mesh	Md. Agric. Slag	Pulverized Limestone	Air Cooled Slag Finer Than 20 mesh	Md. Agric. Slag	Pulverized Limestone	Air Cooled Slag Finer Than 20 mesh	Md. Agric. Slag
4.8	2.50	5.6	8.6	4.00	9.00	13.8	6.00	13.5	20.8
5.0	2.25	5.1	7.8	3.60	8.10	12.5	5.40	12.2	18.7
5.5	1.50	3.4	5.2	2.40	5.40	8.3	3.60	8.1	12.5
6.0	0.75	1.7	2.6	1.20	2.70	4.1	1.80	4.0	6.2

crop yields at lower rates of application. In fact the data presented in the section on crop yields seem to indicate that slag has increased yields of small grain, clover, timothy hay and alfalfa hay even at medium rates of application. For maximum response, however, the rates in Table 49 are indicated by the results of these experiments.

Relative Costs of Slag and Limestone

In the table below the costs of agricultural slag and limestone in bulk are compared at different locations in Maryland.

Table 50

Cost of Slag and Limestone at Different Locations in Maryland

Material	Cost Per Ton of Liming Materials		
	Upper Marlboro	Easton	Salisbury
Agricultural Slag	$4.30	$3.55	$3.55
Limestone	$7.00	$6.00	$7.00-8.00

At a ratio of 3.5 pounds of slag to one pound of limestone it can be seen that slag will not be able to compete with limestone as a liming material.

If the screening process can be changed so that slag finer than 20 mesh is produced at present slag prices, then slag applied at rates of 2.25 pounds to one pound of limestone would be able to compete with limestone in some areas. Further reduction in the cost of slag should be possible with increased volume of business. Movement of slag by barge to the Eastern Shore and Southern Maryland should also help reduce the cost to a value at which Maryland farmers could use slag profitably.

SUMMARY AND CONCLUSIONS

Greenhouse and field experiments with blast furnace slag were conducted on nine important Maryland soils. Air cooled slag was compared with limestone in greenhouse experiments and in one field experiment. The effects of rate of application, and fineness of the two liming materials were investigated both in crop yield response and in chemical changes in the soil. General conclusions of these studies are as follows:

1. Air cooled blast furnace slag was approximately half as effective as equivalent amounts of ground limestone of the same fineness in changing soil pH and exchangeable calcium and hydrogen in these experiments. (Slag produced an average increase of 0.50 pH while limestone produced an average increase of 0.96 pH.)

2. Air cooled slag containing 6.00 per cent magnesium oxide was only twice as effective as limestone containing 0.81 per cent magnesium oxide in increasing magnesium content of soils tested.

3. Decreasing the particle size increased the effectiveness of both slag and limestone. The 10-20 mesh slag grade was only 20 per cent as effective as 80-100 mesh slag, while 50-60 mesh slag was 60 per cent as effective as 80-100 mesh slag.

4. Rates of application for agricultural slag sold in Maryland at the present time should be 3.5 times as great as amounts of well pulverized limestone recommended to attain a pH of 6.5.

5. Slag for agricultural use in Maryland should be screened to remove material coarser than 20 mesh. If this is accomplished 2.25 pounds of slag will have the same effect on soil pH as one pound of limestone.

6. The greatest change in soil reaction occurred within two to four months after application of liming materials.

7. Although crop yield data could not be statistically analyzed, the following trends were observed:

   a. Slag had little effect in increasing yields of corn.

   b. Slag tended to increase yields of straw and grain for both wheat and barley.

   c. Slag seemed to increase yields of clover and timothy hay.

   d. Slag was not as effective as equivalent amounts of limestone of the same fineness in the production of alfalfa hay for the first two years after application. Slag was nearly as effective as limestone in producing alfalfa hay three years after application.

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Table 51

The pH Values as Influenced By Slag Treatment On Mattapex Silt Loam Soil (Princess Anne)
In Field Experiments, 1947 - 1950

Treatment	Slag Passing 100 Mesh Screen	Slag Applied	Time Elapsed Between Treatment and Soil Sampling			
	per cent	tons/acre	2 mos.	1 yr.	2 yrs.	3 yrs.
Air Cooled Slag	14.6	1.56	4.51	4.83	5.02	4.66
Air Cooled Slag	14.6	4.15	4.42	4.91	4.82	5.15
Air Cooled Slag	27.5	1.56	4.48	4.81	—	—
Air Cooled Slag	27.5	4.15	4.54	5.17	—	—
Air Cooled Slag	50.6	1.56	4.62	4.90	5.10	4.58
Air Cooled Slag	50.6	4.15	4.71	4.98	4.86	5.46
Air Cooled Slag	79.4	1.56	4.44	4.87	—	—
Air Cooled Slag	79.4	4.15	5.81	5.42	—	—
Air Cooled Slag	99.3	1.56	4.64	4.85	4.82	5.03
Air Cooled Slag	99.3	4.15	4.96	5.22	4.94	5.31
Untreated	—	None	4.41	4.76	4.71	4.60

Table 52

The pH Values As Influenced By Slag Treatments On Matawan Sandy Loam Soil (Salisbury) In Field Experiments, 1947 - 1950

Treatment	Slag Passing 100 Mesh Screen	Slag Applied	Time Elapsed Between Treatment and Soil Sampling			
	per cent	tons/acre	2 mos.	1 yr.	2 yrs.	3 yrs.
Air Cooled Slag	14.6	0.58	6.29	5.87	6.19	6.45
Air Cooled Slag	14.6	2.16	6.00	5.79	6.12	6.72
Air Cooled Slag	27.5	0.58	6.38	5.82	—	—
Air Cooled Slag	27.5	2.16	6.05	5.96	—	—
Air Cooled Slag	50.6	0.58	6.59	5.97	6.25	6.77
Air Cooled Slag	50.6	2.16	6.67	5.94	6.70	6.72
Air Cooled Slag	79.4	0.58	6.58	5.91	—	—
Air Cooled Slag	79.4	2.16	6.09	5.65	—	—
Air Cooled Slag	99.3	0.58	6.30	5.83	6.49	6.78
Air Cooled Slag	99.3	2.16	6.00	5.79	7.00	6.93
Untreated	—	None	5.87	5.62	6.05	6.14

Table 53

The pH Values As Influenced By Slag Treatments On Matawan Sandy Loam Soil (Salisbury) In Field Experiments, 1947 - 1950

Treatment	Slag Passing 100 Mesh Screen	Slag Applied	Time Elapsed Between Treatment and Soil Sampling			
	per cent	tons/acre	2 mos.	1 yr.	2 yrs.	3 yrs.
Granulated Manganese Slag	16.03	0.81	6.09	5.85	6.58	6.05
Granulated Manganese Slag	16.3	2.99	5.98	5.97	6.60	6.12
Granulated Manganese Slag	27.0	0.81	6.03	5.89	—	5.87
Granulated Manganese Slag	27.0	2.99	5.91	6.09	—	6.25
Granulated Manganese Slag	77.8	0.81	5.91	5.70	5.60	6.25
Granulated Manganese Slag	77.8	2.99	6.10	6.18	6.70	6.26
Untreated	—	None	5.87	5.62	6.05	6.14

Table 54

The pH Values As Influenced By Slag Treatments On Matawan Sandy Loam Soil (Cordova) In Field Experiments, 1947 - 1950

Treatment	Slag Passing 100 Mesh Screen	Slag Applied	Time Elapsed Between Treatment and Soil Sampling			
	per cent	tons/acre	4 mos.	1 yr.	2 yrs.	3 yrs.
Air Cooled Slag	14.6	0.82	5.55	5.54	4.98	4.62
Air Cooled Slag	14.6	2.67	5.44	5.97	5.75	5.32
Air Cooled Slag	27.5	0.82	5.51	5.63	—	—
Air Cooled Slag	27.5	2.67	5.41	5.94	—	—
Air Cooled Slag	50.6	0.82	5.68	5.88	5.50	4.94
Air Cooled Slag	50.6	2.67	5.63	6.00	5.62	5.58
Air Cooled Slag	79.4	0.82	5.58	6.01	—	—
Air Cooled Slag	79.4	2.67	5.82	6.13	—	—
Air Cooled Slag	99.3	0.82	5.80	5.72	5.62	5.02
Air Cooled Slag	99.3	2.67	5.81	6.29	5.72	5.40
Untreated	—	None	5.10	5.56	5.01	4.66

Table 55

The pH Values as Influenced By Slag Treatments On Matawan Sandy Loam Soil (Cordova) in Field Experiments, 1947 - 1950

Treatment	Slag Passing 100 Mesh Screen	Slag Applied	Time Elapsed Between Treatment and Soil Sampling			
	per cent	tons/acre	4 mos	1 yr.	2 yrs.	3 yrs.
Foamed Slag	27.0	0.89	5.34	5.62	4.96	4.76
Foamed Slag	27.00	2.88	5.79	6.11	5.55	4.90
Foamed Slag	76.3	0.89	5.55	5.78	5.23	5.08
Foamed Slag	76.3	2.88	5.89	6.41	5.61	5.82
Untreated	—	None	5.10	5.56	5.01	4.66

Table 56

The pH Values As Influenced By Slag Treatments On Sassafras Silt Loam Soil (Chestertown) In Field Experiments, 1947 - 1950

Treatment	Slag Passing 100 Mesh Screen	Slag Applied	Time Elapsed Between Treatment and Soil Sampling			
	per cent	tons/acre	4 mos.	1 yr.	2 yrs.	3 yrs.
Air Cooled Slag	14.6	1.08	5.76	5.95	5.68	5.59
Air Cooled Slag	14.6	3.48	5.67	5.98	5.78	5.43
Air Cooled Slag	27.5	1.08	5.51	5.59	5.38	—
Air Cooled Slag	27.5	3.48	5.70	6.02	—	—
Air Cooled Slag	50.6	1.08	5.62	5.61	5.49	5.49
Air Cooled Slag	50.6	3.48	6.00	5.93	5.82	5.99
Air Cooled Slag	79.4	1.08	5.40	5.69	—	—
Air Cooled Slag	79.4	3.48	6.29	6.41	5.90	—
Air Cooled Slag	99.3	1.08	5.61	6.02	5.31	5.31
Air Cooled Slag	99.3	3.48	6.14	5.96	6.11	6.18
Untreated	—	None	5.12	5.58	5.14	5.18

Table 57

The pH Values As Influenced By Slag Treatment On Sassafras Silt Loam Soil (Chestertown) in Field Experiments, 1947 - 1950

Treatment	Slag Passing 100 Mesh Screen	Slag Applied	Time Elapsed Between Treatment and Soil Sampling			
	per cent	tons/acre	4 mos.	1 yr.	2 yrs.	3 yrs.
Foamed Slag	27.0	1.16	5.81	5.95	5.72	5.49
Foamed Slag	27.0	3.75	5.98	6.18	5.78	6.05
Foamed Slag	76.3	1.16	5.84	5.80	5.60	5.67
Foamed Slag	76.3	3.75	6.28	6.13	6.18	6.10
Untreated	—	None	5.12	5.58	5.14	5.18

Table 58

The pH Values As Influenced By Slag Treatments On Chester Silt Loam Soil (Sparks) In Field Experiments, 1947 - 1950

Treatment	Slag Passing 100 Mesh Screen per cent	Slag Applied tons/acre	Time Elapsed between Treatment and Soil Sampling			
			4 mos.	1 yr.	2 yrs.	3 yrs.
Air Cooled Slag	14.6	0.65	6.15	6.39	6.60	6.52
Air Cooled Slag	14.6	4.35	6.25	6.52	7.06	6.97
Air Cooled Slag	27.5	0.65	6.40	6.22	7.05	—
Air Cooled Slag	27.5	4.35	6.70	7.11	6.91	—
Air Cooled Slag	50.6	0.65	6.36	6.46	6.75	7.26
Air Cooled Slag	50.6	4.35	6.30	6.67	6.82	7.08
Air Cooled Slag	79.4	0.65	6.00	6.42	6.91	—
Air Cooled Slag	79.4	4.35	6.40	6.76	6.86	—
Air Cooled Slag	99.3	0.65	6.10	6.30	6.61	6.88
Air Cooled Slag	99.3	4.35	6.52	7.02	7.05	7.21
Untreated	—	None	5.80	5.90	6.02	6.18

Table 59

The pH Values As Influenced By Slag Treatments On Chester Silt Loam Soil (Sparks) In Field Experiments, 1947 - 1950

Treatment	Slag Passing 100 Mesh Screen	Slag Applied	Time Elapsed between Treatment and Soil Sampling			
	per cent	tons/acre	4 mos.	1 yr.	2 yrs.	3 yrs.
Granulated Manganese Slag	16.3	0.90	6.21	6.02	6.41	6.71
Granulated Manganese Slag	16.3	6.04	6.45	6.81	7.04	7.14
Granulated Manganese Slag	27.0	0.90	5.95	6.39	6.47	6.76
Granulated Manganese Slag	27.0	6.04	6.70	6.58	6.92	7.21
Granulated Manganese Slag	77.8	0.90	6.50	6.37	6.43	6.87
Granulated Manganese Slag	77.9	6.04	7.13	6.96	6.99	7.09
Untreated	—	None	5.80	5.90	6.02	6.18

Table 60

The pH Values As Influenced By Slag Treatments On Chester Silt Loam Soil (Sparks) In Field Experiments, 1947 - 1950

Treatment	Slag Passing 100 Mesh Screen	Slag Applied	Time Elapsed between Treatment and Soil Sampling			
	per cent	tons/acre	4 mos.	1 yr.	2 yrs.	3 yrs.
Foamed Slag	27.0	0.70	6.20	6.28	6.61	6.55
Foamed Slag	27.0	4.70	6.70	6.77	6.71	6.91
Foamed Slag	76.3	0.70	6.58	6.35	7.02	6.78
Foamed Slag	76.3	4.70	6.85	6.72	6.89	6.58
Untreated	---	None	5.80	5.90	6.02	6.18

Table 61

The pH Values As Influenced By Slag Treatments on Emory Silt Loam Soil (Hagerstown) In Field Experiments, 1947 - 1950

Treatment	Slag Passing 100 Mesh Screen	Slag Applied	Time Elapsed between Treatment and Soil Sampling			
	per cent	tons/acre	4 mos.	1 yr.	2 yrs.	3 yrs.
Air Cooled Slag	14.6	3.84	6.70	6.98	6.99	6.99
Air Cooled Slag	27.5	3.84	6.55	6.76	—	—
Air Cooled Slag	50.6	3.84	6.82	7.10	7.28	7.22
Air Cooled Slag	79.4	3.84	7.09	7.31	—	—
Air Cooled Slag	99.3	3.84	7.56	7.50	7.64	7.75
Untreated	—	None	6.70	6.77	6.80	6.79

Table 62

The pH Values As Influenced By Slag Treatment On Duffield Silt Loam Soil (Frederick) In Field Experiments, 1947 - 1950

Treatment	Slag Passing 100 Mesh Screen	Slag Applied	Time Elapsed between Treatment and Soil Sampling			
	per cent	tons/acre	4 mos.	1 yr.	2 yrs.	3 yrs.
Air Cooled Slag	14.6	3.67	7.40	7.27	7.22	7.38
Air Cooled Slag	27.5	3.67	7.30	7.28	—	—
Air Cooled Slag	50.6	3.67	7.30	7.10	7.04	7.28
Air Cooled Slag	79.4	3.67	7.00	7.08	—	—
Air Cooled Slag	99.3	3.67	6.90	7.49	7.31	7.11
Untreated	—	None	6.60	6.68	6.55	6.75

Table 63

The pH Values As Influenced By Slag Treatments on Glenelg Loam Soil (Jarrettsville)
In Field Experiments, 1947 - 1950

Treatment	Slag Passing 100 Mesh Screen	Slag Applied	Time Elapsed between Treatment and Soil Sampling		
	per cent	tons/acre	4 mos.	1 yr.	2 yrs
Air Cooled Slag	14.6	1.20	5.20	5.35	—
Air Cooled Slag	14.6	4.63	5.30	5.26	—
Air Cooled Slag	27.5	1.20	5.00	5.68	5.30
Air Cooled Slag	27.5	4.63	5.20	6.05	5.88
Air Cooled Slag	50.6	1.20	5.05	5.42	5.08
Air Cooled Slag	50.6	4.63	6.00	6.10	5.84
Air Cooled Slag	79.4	1.20	5.10	5.68	5.38
Air Cooled Slag	79.4	4.63	5.80	6.42	5.92
Air Cooled Slag	99.3	1.20	5.20	5.55	5.19
Air Cooled Slag	99.3	4.63	5.78	6.28	6.14
Untreated	—	None	5.17	5.20	5.12

Table 64

The pH Values As Influenced By Slag and Limestone Treatments On Monmouth Loamy Sand Soil (Marlboro) In Field Experiments, 1948 - 1951

Treatment	Slag Passing 100 Mesh Screen	Slag Applied	Time Elapsed Between Treatment and Soil Sampling			
	per cent	Tons/acre	2 mos.	1 yr.	2 yrs.	3 yrs.
Air Cooled Slag	14.6	1.65	5.48	5.35	5.50	5.52
Coarse Limestone	22.6	1.47	5.22	5.75	5.45	5.63
Air Cooled Slag	14.6	6.10	5.18	5.25	5.35	5.40
Coarse Limestone	22.6	5.54	5.81	6.10	6.20	6.00
Air Cooled Slag	50.6	1.65	5.30	5.55	5.50	5.60
Medium Limestone	27.2	1.47	5.25	5.25	5.30	5.10
Air Cooled Slag	50.6	6.10	5.28	5.82	5.60	6.20
Medium Limestone	27.2	5.54	5.85	5.85	5.95	6.06
Air Cooled Slag	79.4	1.65	5.20	5.73	5.13	5.22
Fine Limestone	77.5	1.47	5.22	5.65	6.09	5.58
Air Cooled Slag	79.4	6.10	5.60	5.85	6.01	6.22
Fine Limestone	77.5	5.54	5.68	6.50	6.45	6.74
Untreated	—	None	4.89	4.95	5.02	4.92

NOTE: Only one replicate analyzed.

Table 49

The pH Values As Influenced By Slag and Limestone Treatments On Monmouth Loamy Sand Soil Three Years After Application

Treatment	Slag Passing 100 Mesh Screen	Slag Applied	pH				Av. pH
	per cent	tons/acre	Rep I	Rep II	Rep III	Rep IV	
Air Cooled Slag	14.6	1.65	5.52	5.50	5.35	5.41	5.44
Coarse Limestone	22.6	1.47	5.63	5.62	5.40	5.76	5.58
Air Cooled Slag	14.6	6.10	5.40	5.66	6.02	6.29	5.72
Coarse Limestone	22.6	5.54	6.00	6.07	5.80	6.49	6.03
Air Cooled Slag	50.6	1.65	5.60	5.54	5.42	5.44	5.49
Medium Limestone	27.2	1.47	5.10	5.66	5.61	5.86	5.46
Air Cooled Slag	50.6	6.10	6.20	5.68	5.65	6.42	5.87
Medium Limestone	27.2	5.54	6.06	6.23	6.18	6.09	6.14
Air Cooled Slag	79.4	1.65	5.22	5.66	5.56	6.02	5.53
Fine Limestone	77.5	1.47	5.58	5.90	5.60	5.77	5.69
AirCooled Slag	79.4	6.10	6.22	6.34	5.91	6.24	6.14
Fine Limestone	77.5	5.54	6.74	6.12	6.48	6.36	6.37
Untreated	—	None	5.92	5.01	5.41	5.28	5.11

Table 66

The Exchangeable Cations As Influenced By Slag Treatments On Mattapex Silt Loam Soil (Princess Anne) in Field Experiments

Treatment	Slag Passing 100 Mesh Screen per cent	Slag Applied Tons/ Acre	Exchangeable Cations After 2 Months me per 100 g soil				
			H	Ca	Mg	Mn	K
Air Cooled Slag	14.6	1.56	4.87	3.04	.20	0.00	0.08
Air Cooled Slag	14.6	4.15	3.94	3.41	0.45	0.08	0.12
Air Cooled Slag	27.5	1.56	5.62	3.15	0.28	0.00	0.13
Air Cooled Slag	27.5	4.15	4.81	2.89	0.45	0.07	0.13
Air Cooled Slag	50.6	1.56	5.46	3.72	0.53	0.00	0.12
Air Cooled Slag	50.6	4.15	—	—	—	—	—
Air Cooled Slag	79.4	1.56	4.44	2.97	0.22	0.06	0.11
Air Cooled Slag	79.4	4.15	—	3.62	0.76	0.16	0.12
Air Cooled Slag	99.3	1.56	4.62	3.69	0.44	0.08	0.12
Air Cooled Slag	99.3	4.15	4.27	3.91	1.67	0.05	0.12
Untreated	—	None	6.22	2.61	0.57	0.02	0.09

Table 67

The Exchangeable Cations As Influenced By Slag Treatments on Matawan Sandy Loam Soil (Salisbury) In Field Experiments

Treatment	Slag Passing 100 mesh screen	Slag Applied Tons/acre	Exchangeable Cations m.e. per 100 g soil						
			H		Ca		Mg		Mn
			2 mo.	1 yr.	2 mo.	1 yr.	2 mo.	1 yr.	2 mo.
Air Cooled Slag	14.6	0.58	2.03	1.75	2.03	1.45	0.97	0.43	0.00
Air Cooled Slag	14.6	2.16	2.00	1.68	1.61	1.44	0.47	0.56	0.00
Air Cooled Slag	27.5	0.58	2.14	1.57	2.06	1.47	0.58	0.50	0.00
Air Cooled Slag	27.5	2.16	2.26	1.65	1.66	1.59	0.44	0.57	0.00
Air Cooled Slag	50.6	0.58	1.74	1.62	2.57	1.67	1.00	0.43	0.00
Air Cooled Slag	50.6	2.16	1.97	1.40	2.01	1.45	0.35	0.54	0.00
Air Cooled Slag	79.4	0.58	—	1.46	2.63	1.91	1.67	0.44	0.00
Air Cooled Slag	79.4	2.16	2.11	1.24	1.45	1.56	0.46	0.33	0.00
Air Cooled Slag	99.3	0.58	1.83	1.49	1.79	1.98	0.69	0.32	0.00
Air Cooled Slag	99.3	2.16	2.02	1.29	1.65	2.13	0.64	0.56	0.01
Untreated	—	None	2.16	1.74	1.52	1.22	0.86	0.39	0.00

Table 66

The Exchangeable Cations As Influenced By Slag Treatments on Matawan Sandy Loam Soil (Salisbury) in Field Experiments

Treatment	Slag Passing 100 Mesh Screen	Slag Applied Tons/Acre	Exchangeable Cations me. per 100g Soil K 2 mo.	K 1 yr.	Ca 2 mo.	Ca 1 yr.	Mg 2 mo.	Mg 1 yr.	Mn 2 mo.
Granulated Manganese Slag	16.3	0.81	1.97	1.52	1.59	1.69	0.66	0.64	0.00
Granulated Manganese Slag	16.3	2.99	—	1.50	1.62	1.79	—	0.49	—
Granulated Manganese Slag	27.0	0.81	1.81	1.42	2.12	1.63	0.51	0.47	0.00
Granulated Manganese Slag	27.0	2.99	2.13	1.37	1.83	1.69	0.61	0.59	0.02
Granulated Manganese Slag	77.8	0.81	2.19	1.45	1.73	1.50	0.57	0.34	0.00
Granulated Manganese Slag	77.8	2.99	—	1.43	1.81	2.22	—	0.39	—
Untreated	—	None	2.16	1.74	1.52	1.22	0.86	0.39	0.00

Table 49

The Exchangeable Cations As Influenced By Slag Treatments on Matawan Sandy Loam Soil (Cordova) In Field Experiments

Treatment	Slag Passing 100 Mesh Screen per cent	Slag Applied Tons/ acre	Exchangeable Cations after 2 mos. me. per 100g soil				
			H	Ca	Mg	Mn	K
Air Cooled Slag	14.6	0.82	2.51	2.63	0.49	0.01	—
Air Cooled Slag	14.6	2.67	2.46	3.64	0.89	0.04	0.11
Air Cooled Slag	27.5	0.82	2.55	2.48	0.41	0.01	0.08
Air Cooled Slag	27.5	2.67	2.42	2.81	0.59	0.03	0.08
Air Cooled Slag	50.6	0.82	1.63	2.75	0.77	0.02	0.11
Air Cooled Slag	50.6	2.67	2.44	4.13	1.29	0.07	0.11
Air Cooled Slag	79.4	0.82	2.20	3.22	0.57	0.02	—
Air Cooled Slag	79.4	2.67	1.73	3.25	0.82	0.02	—
Air Cooled Slag	99.3	0.82	1.54	2.64	0.69	0.02	0.06
Air Cooled Slag	99.3	2.67	1.60	3.48	1.04	0.05	0.13
Untreated	—	None	2.39	2.53	0.51	0.02	0.10

Table 70

The Exchangeable Cations As Influenced By Slag Treatments On Matawan Sandy Loam Soil (Cordova) in Field Experiments

Treatment	Slag Passing 100 Mesh Screen per cent	Slag Applied Tons/ acre	Exchangeable Cations after 2 mos. me. per 100 g soil				
			H	Ca	Mg	Mn	K
Foamed Slag	27.0	0.89	2.90	3.04	0.94	0.04	0.12
Foamed Slag	27.0	2.88	1.72	2.96	1.00	0.04	0.10
Foamed Slag	76.3	0.89	1.82	2.68	0.89	0.04	0.10
Foamed Slag	76.3	2.88	1.50	2.84	0.97	0.01	0.12
Untreated	—	None	2.39	2.53	0.51	0.02	0.10

Table 71

The Exchangeable Cations As Influenced By Slag Treatments On Sassafras Silt Loam Soil (Chestertown) In Field Experiments

Treatment	Slag Passing 100 Mesh Screen per cent	Slag Applied Tons/acre	Exchangeable Cations - me. per 100 g soil											
			K			Ca			Mg			Mn		
			4 mo.	1 yr	2 yrs	4 mo	1 yr	2 yr	4 mo	1 yr	2 yrs	4 mo	1 yr	2 yr
Air Cooled Slag	14.6	1.08	1.17	1.31	1.67	5.96	4.29	5.32	1.22	0.80	0.86	0.14	0.01	0.02
Air Cooled Slag	14.6	3.48	1.20	1.15	1.97	4.68	5.78	4.35	1.34	0.91	0.90	0.12	0.05	0.00
Air Cooled Slag	27.5	1.08	1.36	1.08	2.11	4.95	4.23	5.20	0.82	0.98	0.94	0.14	0.01	0.06
Air Cooled Slag	27.5	3.48	1.11	1.07	1.93	4.73	4.70	—	1.08	0.98	—	0.12	0.02	—
Air Cooled Slag	50.6	1.08	1.25	1.03	1.70	5.08	4.10	4.34	1.50	0.84	0.76	0.08	0.07	0.02
Air Cooled Slag	50.6	3.48	0.93	1.01	1.61	5.42	4.16	4.42	1.50	1.16	1.00	0.10	0.01	0.02
Air Cooled Slag	79.4	1.08	1.30	1.06	1.75	4.24	4.51	—	0.88	1.06	—	0.13	0.02	—
Air Cooled Slag	79.4	3.48	0.93	1.05	1.58	5.45	4.12	—	0.84	0.77	—	0.08	0.01	—
Air Cooled Slag	99.3	1.08	1.33	1.00	1.34	4.68	—	4.33	1.26	—	1.55	0.12	—	—
Air Cooled Slag	99.3	3.48	0.81	1.15	1.64	6.08	4.55	4.55	1.14	0.97	0.97	[illegible]	0.10	0.01
Untreated	—	None	2.42	2.39	2.31	4.08	4.18	4.08	0.86	0.74	0.79	0.12	0.07	0.00

Table 72

The Exchangeable Cations As Influenced By Slag Treatments On Sassafras Silt Loam Soil (Chestertown) In Field Experiments

Treatment	Slag Passing 100 Mesh Screen per cent	Slag Applied Tons/acre	Exchangeable Cations - me. per 100 g soil											
			H			Ca			Mg			Mn		
			4 mo	1 yr	2 yrs	4 mo	1 yr	2 yrs	4 mo	1 yr	2 yrs	4 mo	1 yr	2 yr
Foamed Slag	27.0	1.16	1.84	1.60	2.30	6.38	5.68	4.92	1.32	1.04	0.67	0.09	0.11	0.04
Foamed Slag	27.0	3.75	1.74	1.41	2.10	6.76	5.48	5.18	1.68	1.20	0.92	0.11	0.09	0.03
Foamed Slag	76.0	1.16	2.14	2.15	2.19	6.32	5.50	4.43	1.34	0.72	0.74	0.12	0.06	0.01
Foamed Slag	76.0	3.75	1.70	1.60	1.59	6.35	4.55	5.68	1.30	0.97	0.92	—	0.10	0.04
Untreated	—	None	2.42	2.39	2.31	4.08	4.18	4.08	0.86	0.74	0.79	0.12	0.07	0.00

Table 73

The Exchangeable Cations As Influenced By Slag Treatments on Chester Silt Loam Soil (Sparks) In Field Experiments

Treatment	Slag Passing 100 Mesh Screen per cent	Slag Applied Tons/acre	Exchangeable Cations after 4 mos. me. per 100 g soil				
			H	Ca	Mg	Mn	K
Air Cooled Slag	14.6	0.65	6.25	8.48	1.02	0.06	0.80
Air Cooled Slag	14.6	4.35	4.28	9.90	1.59	0.11	0.63
Air Cooled Slag	27.5	0.65	4.95	8.68	0.99	0.04	—
Air Cooled Slag	27.5	4.35	3.47	10.05	1.70	0.08	0.75
Air Cooled Slag	50.6	0.65	4.30	8.08	0.62	0.02	0.26
Air Cooled Slag	50.6	4.35	3.76	9.35	1.44	0.12	0.25
Air Cooled Slag	79.4	0.65	5.94	7.36	1.22	0.11	0.24
Air Cooled Slag	79.4	4.35	3.23	8.71	—	0.12	0.26
Air Cooled Slag	99.3	0.65	3.30	6.64	1.23	0.26	0.44
Air Cooled Slag	99.3	4.35	4.48	8.60	—	0.04	0.21
Untreated	—	None	6.13	7.47	0.90	0.09	0.60

Table 74

The Exchangeable Cations As Influenced By Slag Treatments On Chester Silt Loam Soil (Sparks) In Field Experiments

Treatment	Slag Passing 100 Mesh Screen per cent	Slag Applied Tons/acre	Exchangeable Cations after 4 mos. me. per 100 g soil				
			H	Ca	Mg	Mn	K
Granulated Manganese Slag	16.3	0.90	6.28	7.75	1.36	0.05	0.24
Granulated Manganese Slag	16.3	6.04	4.24	8.12	—	0.06	0.24
Granulated Manganese Slag	27.0	0.90	5.23	6.69	1.08	0.15	0.15
Granulated Manganese Slag	27.0	6.04	2.44	9.10	1.99	0.24	0.39
Granulated Manganese Slag	77.8	0.90	3.28	14.35	1.15	0.07	0.20
Granulated Manganese Slag	77.8	6.04	0.87	11.55	3.03	0.21	0.38
Untreated	—	None	6.13	7.47	0.90	0.09	0.60

Table 75

The Exchangeable Cations As Influenced By Slag Treatments on Chester Silt Loam Soil (Sparks) In Field Experiments

Treatment	Slag Passing 100 Mesh Screen per cent	Slag Applied Tons/acre	Exchangeable Cations after 4 mos. me. per 100 g. soil				
			H	Ca	Mg	Mn	K
Foamed Slag	27.0	0.70	0.89	8.83	1.52	0.21	0.31
Foamed Slag	27.0	4.70	1.74	9.07	2.02	0.05	0.20
Foamed Slag	76.3	0.70	4.17	9.12	0.99	0.03	0.44
Foamed Slag	76.3	4.70	3.66	10.55	1.07	0.15	0.18
Untreated	—	None	61.3	7.47	0.90	0.09	0.60

Table 76

The Exchangeable Cations As Influenced By Slag Treatments on Emery Silt Loam Soil (Hagerstown)*
In Field Experiments

Treatment	Slag Passing 100 Mesh Screen per cent	Slag Applied Tons/acre	Exchangeable Cations after 4 mos. me. per 100 g. soil				
			H	Ca	Mg	Mn	K
Air Cooled Slag	14.6	3.84	1.14	9.54	1.78	0.00	0.45
Air Cooled Slag	27.5	3.84	0.62	8.32	1.24	0.04	0.36
Air Cooled Slag	50.6	3.84	0.00	9.28	1.18	0.03	0.39
Air Cooled Slag	79.4	3.84	0.00	10.95	1.17	0.00	0.45
Air Cooled Slag	99.3	3.84	0.00	18.15	1.96	0.05	0.30
Untreated	—	None	1.35	7.59	0.70	0.07	0.25

* Only heavy rate of application made on this farm.

Table 77

The Exchangeable Cations As Influenced By Slag Treatments on Duffield Silt Loam Soil (*Frederick*)*
In Field Experiments

Treatment	Slag Passing 100 Mesh Screen per cent	Slag Applied Tons/acre	Exchangeable Cations after 4 mos. me per 100 g. soil				
			H	Ca	Mg	Mn	K
Air Cooled Slag	14.6	3.67	0.00	14.50	2.80	0.12	0.40
Air Cooled Slag	27.5	3.67	0.00	13.73	3.05	0.10	0.42
Air Cooled Slag	50.6	3.67	0.00	11.54	2.47	0.10	0.48
Air Cooled Slag	79.4	3.67	0.00	11.15	2.47	0.15	0.37
Air Cooled Slag	99.3	3.67	0.70	9.75	2.47	0.15	0.45
Untreated	—	None	1.65	7.37	1.24	0.08	0.46

* Only heavy rate of application made on this farm.

Table 78

The Exchangeable Cations As Influenced By Slag Treatments on Monmouth Loamy Sand Soil (Marlboro) In Field Experiments

Treatment	Slag Passing 100 Mesh Screen per cent	Slag Applied Tons/ acres	Exchangeable Cations - me. per 100 g soil											
			H			Ca			Mg			Mn		
			2 mo	1 yr	2 yrs	2 mo	1 yr	2 yrs	2 mo	1 yr	2 yrs	2 mo	1 yr	2 yr
Air Cooled Slag	14.6	1.65	3.37	3.10	3.12	3.42	3.63	4.25	0.49	0.39	0.90	0.03	0.03	0.01
Air Cooled Slag	14.6	6.10	3.24	2.25	2.74	3.52	3.27	3.95	0.43	0.38	0.76	0.02	0.03	0.01
Air Cooled Slag	50.6	1.65	3.39	2.49	3.06	4.72	4.11	4.15	0.65	0.69	1.00	0.01	0.05	0.00
Air Cooled Slag	50.6	6.10	3.12	2.25	2.18	3.82	4.50	4.49	0.29	0.79	0.90	0.02	0.02	0.01
Air Cooled Slag	79.4	1.65	3.30	2.63	2.85	3.03	3.27	3.78	0.29	0.37	0.77	0.04	0.03	0.01
Air Cooled Slag	79.4	6.10	[illegible]	2.47	2.28	5.25	5.96	5.50	1.25	0.99	—	0.03	0.03	0.01
Untreated	—	None	3.35	3.16	3.69	3.28	3.45	3.39	0.58	1.28	0.74	0.06	0.03	0.01

Table 79

The Exchangeable Cations as Influenced by Liming Treatments on Monmouth Loamy Sand Soil (Marlboro) In Field Experiments

Treatment	Slag Passing 100 Mesh Screen per cent	Slag Applied Tons/acre	Exchangeable Cations - m.e. per 100 g soil: H 4 mo	H 1 yr	H 2 yrs	Ca 4 mo	Ca 1 yr	Ca 2 yrs	Mg 4 mo	Mg 1 yr	Mg 2 yrs	Mn 4 mo	Mn 1 yr	Mn 2 yrs
Coarse Limestone	22.6	1.47	2.89	2.11	2.41	5.90	5.30	4.68	1.61	2.43	1.19	0.03	0.02	0.01
Coarse Limestone	22.6	5.54	2.01	2.03	1.46	5.11	5.20	5.75	0.95	0.74	0.74	0.03	0.02	0.01
Medium Limestone	27.2	1.47	3.26	2.92	3.19	4.80	3.86	3.51	0.62	1.77	0.66	0.06	0.03	0.01
Medium Limestone	27.2	5.54	2.00	0.91	1.95	5.65	6.46	4.97	0.87	1.65	0.86	0.05	0.02	0.00
Fine Limestone	77.5	1.47	3.31	2.56	1.76	3.66	3.98	4.97	0.70	0.58	0.53	0.04	0.02	0.01
Fine Limestone	77.5	5.54	2.91	1.14	1.11	5.09	5.55	5.25	2.00	1.97	1.48	0.02	0.01	0.00
Untreated	—	None	3.35	3.16	3.69	3.28	3.45	3.39	0.58	1.28	0.74	0.06	0.03	0.01

Table 60

The Exchangeable Cations and pH Values As Influenced By Slag Treatments on Monmouth Loamy Sand Soil in Greenhouse Experiments

Treatment	Fineness of Slag	Slag Applied	pH		Exchangeable Cations After 10 months m.e. per 100 g		
	Screen Size		After 10 months	After 14 months	H	Ca	Mg
Air Cooled Slag	4 - 10	1.66	—	—	—	—	—
Air Cooled Slag	4 - 10	6.10	5.42	4.98	2.80	4.37	0.39
Air Cooled Slag	10 - 20	1.66	5.13	4.86	2.49	4.19	0.44
Air Cooled Slag	10 - 20	6.10	5.54	5.53	1.60	4.62	0.54
Air Cooled Slag	50 - 60	1.66	5.48	5.61	2.12	4.51	0.64
Air Cooled Slag	50 - 60	6.10	6.34	5.62	0.96	5.90	0.60
Air Cooled Slag	80 - 100	1.66	5.80	6.40	1.62	4.78	0.68
Air Cooled Slag	80 - 100	6.10	6.48	6.77	0.80	6.04	0.88
Air Cooled Slag	Through 200	1.66	6.30	5.95	1.40	5.33	0.92
Air Cooled Slag	Through 200	6.10	7.42	7.55	0.00	6.94	1.54
Untreated	—	None	5.07	4.84	3.20	4.20	0.26

All values are averages of two replicates

* As an example "4 - 10" indicates material passing through a screen with 4 meshes per inch and retained on a screen with 10 meshes per inch.

Table 81

The Exchangeable Cations and pH Values As Influenced By Limestone Treatments on Monmouth Loamy Sand Soil in Greenhouse Experiments

Treatment	Fineness of Slag	Slag Applied	pH		Exchangeable Cations After 10 months m.e. per 100 g		
	Screen Size	Ton/acre	After 10 months	After 10 months	H	Ca	Mg
Limestone	4 - 10	1.42	5.16	4.98	1.85	4.16	0.38
Limestone	4 - 10	5.25	—	—	—	—	—
Limestone	10 - 20	1.42	5.42	5.40	1.51	4.78	0.48
Limestone	10 - 20	5.25	6.17	6.65	0.48	6.10	0.50
Limestone	50 - 60	1.42	6.28	6.17	1.20	5.72	0.65
Limestone	50 - 60	5.25	7.17	7.13	0.00	9.98	0.56
Limestone	80 - 100	1.42	6.42	6.14	0.70	6.02	0.70
Limestone	80 - 100	5.25	7.33	7.21	0.00	10.84	0.64
Limestone	Through 200	1.42	7.06	6.14	0.18	6.07	0.70
Limestone	Through 200	5.25	7.93	7.58	0.00	11.56	0.74
Untreated	—	None	5.07	4.84	3.20	4.20	0.25

All values are averages of two replicates

* As an example "4 - 10" indicates material passing through a screen with 4 meshes per inch and retained on a screen with 10 meshes per inch.

Table 62

The Exchangeable Cations and pH Values As Influenced By Slag Treatments on Glenelg Loam Soil in Greenhouse Experiments

Treatment	Fineness of Slag	Slag Applied	pH		Exchangeable Cations After 10 months M.e. per 100 g		
	Screen Size *	Tons/Acre	After 10 months	After 14 months	H	Ca	Mg
Air Cooled Slag	4 - 10	1.58	—	—	—	—	—
Air Cooled Slag	4 - 10	6.09	—	—	—	—	—
Air Cooled Slag	10 - 20	1.58	5.94	6.74	1.60	9.57	1.21
Air Cooled Slag	10 - 20	6.09	5.89	6.63	1.44	9.55	1.33
Air Cooled Slag	50 - 60	1.58	6.00	6.70	1.35	9.79	1.19
Air Cooled Slag	50 - 60	6.09	6.18	6.88	0.85	10.40	1.48
Air Cooled Slag	80 - 100	1.58	6.10	6.72	1.33	10.13	1.27
Air Cooled Slag	80 - 100	6.09	6.30	7.06	0.62	10.66	1.57
Air Cooled Slag	Through 200	1.58	—	—	—	—	—
Air Cooled Slag	Through 200	6.09	—	—	—	—	—
Untreated	—	None	5.88	6.67	1.84	9.28	1.11

All values are averages of two replicates

* As an example "4 - 10" indicates material passing through a screen with 4 meshes per inch and retained on a screen with 10 meshes per inch.

Table 63

The Exchangeable Cations and pH Values As Influenced By Limestone Treatments on Glenelg Loam Soil in Greenhouse Experiments

Treatment	Fineness of Limestone Screen Size *	Limestone Applied Tons/acre	pH		Exchangeable Cations After 10 months m.e. per 100 g		
			After 10 months	After 14 months	H	Ca	Mg
Limestone	4 - 10	1.36	—	—	—	—	—
Limestone	4 - 10	5.23	—	—	—	—	—
Limestone	10 - 20	1.36	5.96	6.74	1.86	9.52	1.11
Limestone	10 - 20	5.23	6.00	6.89	1.20	10.24	1.15
Limestone	50 - 60	1.36	6.16	6.94	1.10	10.39	1.06
Limestone	50 - 60	5.23	6.52	7.46	0.00	12.74	1.14
Limestone	80 - 100	1.36	6.24	7.06	0.87	10.76	1.01
Limestone	80 - 100	5.23	6.65	7.58	0.00	13.56	0.96
Limestone	Through 200	1.36	—	—	—	—	—
Limestone	Through 200	5.23	—	—	—	—	—
Untreated	—	None	5.88	6.67	1.84	9.28	1.11

All values are averages of two replicates

* As an example "4 - 10" indicates material passing through a screen with 4 meshes per inch and retained on a screen with 10 meshes per inch.

Table 84

The Exchangeable Cations and pH Values As Influenced By Slag Treatments on Mattapex Silt Loam Soil in Greenhouse Experiments

Treatment	Fineness of Slag Screen Size*	Slag Applied Tons/Acre	pH		Exchangeable Cations After 10 months m.e. per 100g		
			After 10 months	After 14 months	H	Ca	Mg
Air Cooled Slag	4 - 10	2.06	—	—	—	—	—
Air Cooled Slag	4 - 10	5.47	—	—	—	—	—
Air Cooled Slag	10 - 20	2.06	4.26	4.82	7.38	4.16	0.97
Air Cooled Slag	10 - 20	5.47	4.40	4.92	6.[illegible]5	4.64	1.22
Air Cooled Slag	50 - 60	2.06	4.50	5.19	5.87	4.95	1.31
Air Cooled Slag	50 - 60	5.47	4.92	5.60	5.01	5.48	1.74
Air Cooled Slag	80 - 100	2.06	4.68	5.42	5.50	5.38	1.44
Air Cooled Slag	80 - 100	5.47	5.14	5.86	4.10	6.44	1.69
Air Cooled Slag	Through 200	2.06	—	—	—	—	—
Air Cooled Slag	Through 200	5.47	—	—	—	—	—
Untreated	—	None	4.25	4.68	7.41	3.26	0.88

All values are averages of two replicates

* As an example, "4 - 10" indicates material passing through a screen with 4 meshes per inch and retained on a screen with 10 meshes per inch.

Table 85

The Exchangeable Cations and pH Values As Influenced By Limestone Treatments on Mattapex Silt Loam Soil in Greenhouse Experiments

Treatment	Fineness of Limestone Screen Size *	Limestone Applied tons/acre	pH After 10 months	pH After 14 months	Exchangeable Cations After 10 months m.e. per 100g K	Ca	Mg
Limestone	4 - 10	1.77	—	—	—	—	—
Limestone	4 - 10	4.68	—	—	—	—	—
Limestone	10 - 20	1.77	4.46	4.90	.47	5.38	0.95
Limestone	10 - 20	4.68	4.48	5.65	.02	6.45	1.03
Limestone	50 - 60	1.77	4.70	5.54	.33	6.32	1.05
Limestone	50 - 60	4.68	5.45	6.81	.92	10.72	1.06
Limestone	80 - 100	1.77	5.04	5.44	.08	6.45	1.15
Limestone	80 - 100	4.68	5.96	6.80	.82	10.36	1.19
Limestone	Through 200	1.77	—	—	—	—	—
Limestone	Through 200	4.68	—	—	—	—	—
Untreated	—	None	4.25	4.68	7.41	3.26	0.88

All values are averages of two replicates

* As an example, "4 - 10" indicates material passing through a screen with 4 meshes per inch and retained on a screen with 10 meshes per inch.

Table 66

Response of Wheat and Hay to Slag Treatments on Mattapex Silt Loam Soil (Princess Anne)

Treatment	Slag Passing 100 Mesh Screen	Slag Applied	Wheat – 2 months After Treatment				Clover – Timothy Hay (1 year after treatment)	
			Straw		Grain			
	per cent	Tons/acre	Tons/acre	Relative Value*	Bu/acre	Relative Value*	Tons/acre	Relative Value *
Air Cooled Slag	14.6	1.56	1.22	90	11.2	113	0.55	250
Air Cooled Slag	14.6	4.15	1.54	114	12.3	124	0.67	304
Air Cooled Slag	27.5	1.56	1.25	93	12.8	129	0.57	259
Air Cooled Slag	27.5	4.15	1.77	131	12.2	123	0.54	246
Air Cooled Slag	50.6	1.56	1.39	103	10.2	103	0.59	268
Air Cooled Slag	50.6	4.15	1.10	81	10.7	108	0.61	278
Air Cooled Slag	79.4	1.56	1.46	108	8.1	82	0.68	309
Air Cooled Slag	99.3	1.56	1.50	111	10.1	102	0.66	300
Air Cooled Slag	99.3	4.15	1.26	93	10.4	105	0.76	346
Untreated	—	0.00	1.35	100	9.9	100	0.22	100

$$* \text{ Relative value} = \frac{\text{average yield per treatment}}{\text{average yield of untreated plots}} \times 100$$

Table 67

Response of Hay and Corn to Slag Treatments on Matawan Sandy Loam Soil (Salisbury)

Treatment	Slag Passing 100 Mesh Screen	Slag Applied	Clover - Timothy Hay 2 months after treatment		Corn 1 year after treatment		Corn 2 years after treatment	
	per cent	Tons/acre	Tons/acre	Relative Value*	Bu/acre	Relative Value*	Bu/acre	Relative Value*
Air Cooled Slag	14.6	0.58	0.70	140	28.9	164	35.7	97
Air Cooled Slag	14.6	2.16	0.70	140	20.6	117	32.4	88
Air Cooled Slag	27.5	0.58	0.80	160	20.4	116	33.9	92
Air Cooled Slag	27.5	2.16	0.60	120	22.0	125	36.5	99
Air Cooled Slag	50.6	0.58	0.90	180	29.2	166	37.0	100
Air Cooled Slag	50.6	2.16	0.60	120	19.5	111	35.4	96
Air Cooled Slag	79.4	0.58	0.80	160	25.6	145	36.6	99
Air Cooled Slag	79.4	2.16	0.70	140	20.5	117	41.7	113
Air Cooled Slag	99.3	0.58	0.70	140	17.7	101	33.7	91
Air Cooled Slag	99.3	2.16	0.70	140	23.9	136	31.5	85
Untreated	—	none	0.50	100	17.6	100	36.9	100

$$* \text{ Relative value} = \frac{\text{average yield per treatment}}{\text{average yield of untreated plots}} \times 100$$

Table 88

Response of Hay and Corn to Slag Treatments on Matawan Sandy Loam Soil (Salisbury)

Treatment	Slag Passing 100 Mesh Screen	Slag Applied	Clover - Timothy Hay 2 months after treatment		Corn 1 year after treatment		Corn 2 years after treatment	
	per cent	Tons/ acre	Tons/ acre	Relative Value*	Bu/acre	Relative Value*	Bu/acre	Relative Value*
Granulated Manganese Slag	16.3	0.81	0.70	140	27.7	157	33.6	91
Granulated Manganese Slag	16.3	2.99	0.70	140	31.3	178	29.0	79
Granulated Manganese Slag	27.0	0.81	1.00	200	23.3	132	35.9	97
Granulated Manganese Slag	27.0	2.99	0.90	180	23.4	133	36.6	99
Granulated Manganese Slag	77.8	0.81	1.00	200	30.2	171	37.5	102
Granulated Manganese Slag	77.8	2.99	1.10	220	31.5	179	36.2	88
Untreated	—	none	0.50	100	17.6	100	36.9	100

* Relative value = $\frac{\text{average yield per treatment}}{\text{average yield of untreated plots}} \times 100$

Table 89

Response of Wheat and Corn to Slag Treatments on Matawan Fine Sandy Loam Soil (Cordova)

Treatment	Slag Passing 100 Mesh Screen	Rate of Application	Shelled Corn 4 months after treatment		Wheat - 1 year after treatment			
					Straw		Grain	
	per cent	Tons/ acre	Bu/acre	Relative Value*	Tons/ acre	Relative Value*	Bu/acre	Relative Value*
Air Cooled Slag	14.6	0.82	69.8	101	1.10	108	11.9	100
Air Cooled Slag	14.6	2.67	69.3	100	0.95	93	10.0	84
Air Cooled Slag	27.5	0.82	74.9	108	1.02	100	11.4	96
Air Cooled Slag	27.5	2.67	78.3	113	1.26	123	13.0	109
Air Cooled Slag	50.6	0.82	68.6	99	1.25	122	12.5	105
Air Cooled Slag	50.6	2.67	69.9	101	1.60	157	15.5	130
Air Cooled Slag	79.4	0.82	75.2	109	1.36	133	13.4	113
Air Cooled Slag	79.4	2.67	70.1	101	1.56	153	17.3	145
Air Cooled Slag	99.3	0.82	72.7	105	1.55	152	16.9	142
Air Cooled Slag	99.3	2.67	74.4	107	1.64	163	16.7	140
Untreated	—	none	69.2	100	1.02	100	11.9	100

$$* \text{ Relative value} = \frac{\text{average yield per treatment}}{\text{average yield of untreated plots}} \times 100$$

Table 90

Response of Wheat and Corn to Slag Treatments on Matawan Fine Sandy Loam Soil (Cordova)

Treatment	Slag Passing 100 Mesh Screen	Rate of Application	Shelled Corn 4 months after treatment		Wheat - 1 year after treatment			
					Grain		Grain	
	per cent	Tons/acre	Bu/acre	Relative Value *	Tons/acre	Relative Value*	Bu/acre	Relative Value*
Foamed Slag	27.0	0.89	73.3	106	1.16	114	13.1	110
Foamed Slag	27.0	2.88	73.0	105	1.47	144	16.6	139
Foamed Slag	76.3	0.89	73.8	107	1.21	119	13.4	113
Foamed Slag	76.3	2.88	76.0	110	1.44	141	15.5	130
Untreated	---	none	69.2	100	1.02	100	11.9	100

$$* \text{ Relative value} = \frac{\text{average yield per treatment}}{\text{average yield of untreated plots}} \quad 100$$

Table 91

Response of Corn, Wheat and Hay to Slag Treatments on Sassafras Silt Loam Soil (Chestertown)

Treatment	Slag Passing 100 Mesh Screen	Slag Applied	Shelled Corn 4 months after treatment		Wheat - 1 year after treatment				Clover-Timothy Hay 2 years after treatment	
					Straw		Grain			
	per cent	Tons/ acre	Bu/acre	Relative Value*	Tons/ acre	Relative Value*	Bu/acre	Relative Value*	Tons/ acre	Relative Value*
Air Cooled Slag	14.6	1.08	94.3	103	1.72	113	15.5	101	1.96	96
Air Cooled Slag	14.6	3.48	97.1	106	1.72	113	16.0	104	1.82	89
Air Cooled Slag	27.5	1.08	91.8	100	1.59	105	15.7	103	2.10	103
Air Cooled Slag	27.5	3.48	92.7	102	1.78	117	17.2	112	2.07	102
Air Cooled Slag	50.6	1.08	93.0	102	1.74	114	16.6	109	2.03	99
Air Cooled Slag	50.6	3.48	87.7	95	1.81	119	17.8	116	2.02	99
Air Cooled Slag	79.4	1.08	93.6	103	1.68	109	16.7	109	1.95	96
Air Cooled Slag	79.4	3.48	96.1	105	1.80	118	16.9	110	1.84	90
Air Cooled Slag	99.3	1.08	92.8	102	1.56	103	15.2	99	1.78	87
Air Cooled Slag	99.3	3.48	94.3	103	1.91	125	18.1	118	2.04	100
Untreated		none	91.3	100	1.52	100	15.3	100	2.04	100

$$\text{*Relative value} = \frac{\text{average yield per treatment}}{\text{average yield of untreated plots}} \times 100$$

Table 92

Response of Corn, Wheat and Hay to Slag Treatments on Sassafras Silt Loam Soil (Chestertown)

Treatment	Slag Passing 100 Mesh Screen	Slag Applied	Shelled corn 4 months after treatment		Wheat - 1 year after treatment				Clover-Timothy Hay 2 years after treatment	
					Straw		Grain			
	per cent	Tons/ acre	Bu/acre	Relative Value*	Bu/acre	Relative Value*	Bu/acre	Relative Value*	Tons/ acre	Relative Value*
Foamed Slag	27.0	1.16	90.8	99	1.64	108	15.0	98	1.83	90
Foamed Slag	27.0	3.75	97.6	107	2.00	131	18.5	121	2.12	104
Foamed Slag	76.0	1.16	96.6	106	1.78	117	15.2	99	1.70	83
Foamed Slag	76.0	3.75	93.1	102	1.78	117	17.6	115	1.76	86
Untreated		none	91.3	100	1.52	100	15.3	100	2.04	100

* Relative value = (average yield per treatment / average yield of untreated plots) x 100

Table 93

Response of Corn and Wheat to Slag Treatments on Chester Silt Loam Soil (Sparks)

Treatment	Slag Passing 100 Mesh Screen	Slag Applied	Shelled Corn 4 months after treatment		Wheat - 1 year after treatment				Wheat - 2 years after treatment			
					Straw		Grain		Straw		Grain	
	per cent	Tons/ acre	Bu/ acre	Relative Value*	Tons/ acre	Relative Value*	Bu/ acre	Relative Value*	Tons/ acre	Relative Value*	Bu/ acre	Relative Value*
Air Cooled Slag	14.6	0.65	65.6	106	2.34	.94	22.0	83	3.48	108	32.2	108
Air Cooled Slag	14.6	4.35	66.7	108	3.02	122	28.6	108	3.35	104	33.1	111
Air Cooled Slag	27.5	0.65	63.1	102	2.38	96	22.4	84	3.43	106	32.9	110
Air Cooled Slag	27.5	4.35	63.0	102	3.11	125	27.6	104	3.60	112	34.1	114
Air Cooled Slag	50.6	0.65	61.6	100	2.85	115	25.8	97	3.57	111	33.1	111
Air Cooled Slag	50.6	4.35	58.2	96	3.05	123	29.0	109	3.70	115	38.8	130
Air Cooled Slag	79.4	0.65	64.7	105	2.86	115	26.3	99	3.65	113	32.2	108
Air Cooled Slag	79.4	4.35	67.1	109	3.08	124	31.6	119	3.77	117	37.4	125
Air Cooled Slag	99.3	0.65	66.4	108	2.76	111	23.9	90	3.45	107	31.4	105
Air Cooled Slag	99.3	4.35	62.6	101	2.61	105	28.1	106	3.64	113	35.7	120
Untreated	—	none	61.6	100	2.48	100	26.5	100	3.22	100	29.8	100

$$* \text{ Relative value} = \frac{\text{average yield per treatment}}{\text{average yield of untreated plots}} \times 100$$

Table 94

Response of Corn and Wheat to Slag Treatments on Chester Silt Loam Soil (Sparks)

Treatment	Slag Passing 100 Mesh Screen	Slag Applied	Shelled Corn 4 months after treatment		Wheat - 1 year after treatment				Wheat - 2 years after treatment			
					Straw		Grain		Straw		Grain	
	per cent	Tons/ acre	Bu/ acre	Relative Value*	Tons/ acre	Relative Value*	Bu/ acre	Relative Value*	Tons/ acre	Relative Value*	Bu/ acre	Relative Value*
Granulated Manganese Slag	16.3	0.90	60.9	99	2.40	97	26.4	99	3.16	98	29.0	97
Granulated Manganese Slag	16.3	6.04	65.2	106	2.54	102	28.2	106	3.24	101	29.8	100
Granulated Manganese Slag	27.0	0.90	62.8	102	2.68	108	29.3	110	2.98	92	38.6	129
Granulated Manganese Slag	27.0	6.04	-	-	2.86	115	30.2	114	3.60	112	32.0	107
Granulated Manganese Slag	77.8	0.90	59.1	96	2.42	98	25.7	97	2.99	93	28.5	96
Granulated Manganese Slag	77.8	6.04	-	-	2.60	105	28.8	113	3.38	105	29.5	98
Untreated	-	none	61.6	100	2.48	100	26.5	100	3.22	100	29.8	100

$$* \text{ Relative value} = \frac{\text{average yield per treatment}}{\text{average yield of untreated plots}} \times 100$$

Table 95

Response of Corn and Wheat to Slag Treatments on Chester Silt Loam Soil (Sparks)

Treatment	Slag Passing 100 Mesh Screen	Slag Applied	Shelled Corn 4 months after treatment		Wheat - 1 year after treatment				Wheat - 2 years after treatment			
					Straw		Grain		Straw		Grain	
	per cent	Tons/ acre	Bu/ acre	Relative Value*	Tons/ acre	Relative Value*	Bu/ acre	Relative Value*	Tons/ acre	Relative Value*	Bu/ acre	Relative Value*
Foamed Slag	27.0	0.70	64.1	104	3.07	124	30.9	117	3.31	103	33.6	113
Foamed Slag	27.0	4.70	62.9	102	2.75	111	31.8	120	2.80	87	29.8	100
Foamed Slag	76.3	0.70	65.7	106	2.77	112	30.8	116	3.44	107	32.8	110
Foamed Slag	76.3	4.70	70.2	114	2.96	119	34.0	128	3.20	99	32.3	108
Untreated	-	none	61.6	100	2.48	100	26.5	100	3.22	100	29.8	100

$$* \text{ Relative value} = \frac{\text{average yield per treatment}}{\text{average yield of untreated plots}} \times 100$$

Table 96

Response of Hay, Corn and Wheat to Slag Treatments on Emory Silt Loam Soil. (Hagerstown)

Treatment	Slag Passing 100 Mesh Screen	Slag Applied	Clover and Timothy Hay 2 months after treatment		Shelled Corn 1 year after treatment		Wheat 2 years after treatment			
							Straw		Grain	
	per cent	Tons/acre	Tons/acre	Relative Value*	Tons/acre	Relative Value*	Tons/acre	Relative Value*	Bu/acre	Relative Value*
Air Cooled Slag	14.6	3.84	0.89	92	20.7	81	2.09	85	19.6	91
Air Cooled Slag	27.5	3.84	0.95	105	26.0	102	2.52	103	22.5	105
Air Cooled Slag	50.6	3.84	0.67	74	30.8	120	2.49	101	24.1	113
Air Cooled Slag	79.4	3.84	0.86	96	37.5	147	2.80	114	25.0	117
Air Cooled Slag	99.3	3.84	0.91	101	43.7	171	2.68	109	29.8	139
Untreated	—	none	0.90	100	25.6	100	2.45	100	21.4	100

$$* \text{ Relative value} = \frac{\text{average yield per treatment}}{\text{average yield of untreated plots}} \times 100$$

Table 97

Response of Hay and Barley to Slag Treatments on Duffield Silt Loam Soil** (Frederick)

Treatment	Slag Passing 100 Mesh Screen	Slag Applied	Clover Hay 2 months after treatment		Barley 2 years after treatment			
					Straw		Grain	
	per cent	Tons/acre	Tons/acre	Relative Value*	Tons/acre	Relative Value*	Bu/acre	Relative Value*
Air Cooled Slag	14.6	3.67	1.30	91	1.79	106	24.4	111
Air Cooled Slag	27.5	3.67	1.25	87	1.74	103	24.1	109
Air Cooled Slag	50.6	3.67	1.05	73	2.04	121	24.4	111
Air Cooled Slag	79.4	3.67	1.05	73	1.47	87	19.9	90
Air Cooled Slag	99.3	3.67	1.08	75	1.39	83	22.9	103
Untreated	—	none	1.43	100	1.68	100	22.2	100

* Relative value = $\frac{\text{average yield per treatment}}{\text{average yield of untreated plots}} \times 100$

** The crop yields of 1948 were accidentally destroyed by the farmer

Table 98

Response of Corn and Wheat to Slag Treatments on Glenelg Loam Soil (Jarrettsville) **

Treatment	Slag Passing 100 Mesh Screen	Slag Applied	Shelled corn 1 year after treatment		Wheat - 2 years after treatment			
					Straw		Grain	
	per cent	Tons/acre	Bu/acre	Relative Value*	Tons/acre	Relative Value*	Bu/acre	Relative Value*
Air Cooled Slag	14.6	1.20	42.9	104	2.39	108	26.1	115
Air Cooled Slag	14.6	4.63	38.2	93	2.59	117	26.8	118
Air Cooled Slag	27.5	1.20	41.2	100	2.42	109	24.7	109
Air Cooled Slag	27.5	4.63	37.7	92	2.54	114	27.2	120
Air Cooled Slag	50.6	1.20	39.9	97	2.71	122	26.5	117
Air Cooled Slag	50.6	4.63	43.4	106	2.72	122	28.6	126
Air Cooled Slag	79.4	1.20	37.5	93	2.35	106	26.0	114
Air Cooled Slag	79.4	4.63	43.3	106	2.60	117	28.6	126
Air Cooled Slag	99.3	1.20	37.9	92	2.62	118	27.5	121
Air Cooled Slag	99.3	4.63	39.1	95	2.69	121	28.8	127
Untreated		none	41.0	100	2.22	100	22.7	100

$$\text{* Relative value} = \frac{\text{average yield per treatment}}{\text{average yield of untreated plots}} \times 100$$

** Crop yields of 1947 were accidentally destroyed by the farmer.

VITA

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