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BASIC SLAG.

By B. C. Aston, F.I.C., F.C.S., Agricultural Chemist.

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BASIC SLAG.

THE PHILOSOPHER'S STONE OF THE PASTORALIST.

By B. C. Aston, F.I.C., F.C.S.

The philosopher's stone for which the alchemists vainly sought was, they hoped, a substance by which base metals might be transmuted into gold. Basic slag, of all substances, most nearly realizes the pastoralist's dream of a magic something, the touch of which should clothe the languishing earth with a perennial verdure.

In the following pages endeavour will be made to bring home to the reader some of the leading facts of a substance concerning the effects of which sober men of science, agriculturists, and other practical men guiltless of flights of fancy have used such terms as "wonderful" and "marvellous."

New Zealand is almost wholly a pastoral country. More than three-fourths of the total exports may be reckoned as directly derived from pasture. There is no other known substance which has been so successful in ameliorating poor pastures in temperate moist climates as basic slag. The subject is, therefore, one of extreme importance to the farmer and to the Dominion. This bulletin deals with the origin and nature of basic slag, and the results of its application to the soil.

Origin.

Basic slag, also known as "basic cinder," "Thomas slag," "Thomas phosphate," or "Thomas meal," and in America as "odourless phosphate," is the finely ground furnace-slag obtained as a by-product in the Thomas-Gilchrist basic process of making mild steel.* The

* Basic slag is now also made by at least one other process as a by-product, and even, it is stated, as a main product.

process, which was introduced in 1879, entails heating the molten pig iron to a very high temperature in a pear-shaped vessel known as a Bessemer converter. The walls of this vessel are lined with lime or dolomite (magnesian limestone), or a mixture of dolomite, lime, and tar. An air-blast is blown through the molten mass, whereby the impurities of the iron, consisting of the elements phosphorus, manganese, silicon, carbon, and sometimes sulphur and vanadium, are oxidized or burnt. These oxides are either basic or acidic, and are capable of combining with each other (excepting the carbon-oxides, which are volatilized), with the lime and iron-oxide which are thrown into the molten mass, or with the lime and magnesia of the furnace-lining, to form a slag which floats on the surface of the molten metal. The further details of the process do not concern the agriculturist, and need not be here narrated. The slag is removed by suitable means from the surface of the molten metal, allowed to cool, and finally pulverized. The ground slag is now a marketable article, and without further treatment is in the most suitable condition for applying to the soil.

Discovery of Fertilizing-value.

The basic process of making mild steel was an accomplished fact in 1879; but no use was found for the thousands of tons of waste slag until three or four years later, in 1883, when it began to attract attention as a fertilizer. Comprehensive experiments, both in field and laboratory, were then undertaken, notably by Professor Wagner, of Darmstadt, in Germany, and by Messrs. Wrightson and Munro in England, with the result that the use of finely ground basic cinder was fully justified, on soils rich in organic matter,* for all crops; on all soils, if not too dry in character; and on clay soils poor in lime.

Growth as a Fertilizer.

Since 1886 basic slag has been on the market, and no other fertilizer, has advanced so rapidly in the farmers' favour. In 1887, 300,000 tons were used in Germany alone. In 1880 the production of this slag in the Grand Duchy of Luxemburg and Germany was only 4,326 tons, in 1890 it was 358,320 tons, and in 1899 it had risen to 953,570 tons. The production of basic slag in Europe in 1901 exceeded 1,700,000 tons.

* As showing the intense solvent power which organic matter has on slag phosphate, an experiment made by Albert may be quoted: 1 gram of basic slag and 100 grams of peat were mixed together in 1 liter of water, and it was found that after standing for fourteen days 79 per cent. of the phosphoric anhydride had become soluble.

As showing how the slag is distributed, the following figures (for 1899) showing production and consumption may be cited :—

	Production. Tons.	Consumption. Tons.
Germany	1,009,000	895,000
France	166,000	170,000
Great Britain	267,000	128,000
Austria-Hungary	63,000	92,000
Belgium	131,000	89,000
Sweden	..	58,000
Italy	..	56,000

In New Zealand basic slag has steadily increased in popularity, as the importations for the undermentioned years show :—

	Tons.	Value.
Year ending 31st March, 1909	4,321	£14,595
,, ,, 1910	5,013	£16,126
,, ,, 1911	8,670	£28,231
,, ,, 1912	16,107	£52,976
,, ,, 1913	20,133	£66,389

The following table shows how the importations are distributed throughout the country :—

Importations of Basic Slag.

	For Years			
	1910. Tons.	1911. Tons.	1912. Tons.	1913. Tons.
Auckland ..	3,518	6,529	10,877	12,889
*New Plymouth ..	328	588	1,875	823
Wanganui ..	30	..	..	..
Poverty Bay ..	..	..	..	20
Napier	..	10	175	225
Wellington ..	947	1,148	2,101	5,133
Nelson	25	170	30	204
Blenheim ..	..	..	20	..
Timaru	..	..	50	156
Lyttelton ..	155	125	400	400
Dunedin ..	..	20	434	50
Invercargill ..	10	110	265	233
	5,013	8,700	16,227	20,133

*The figures for New Plymouth and Wellington must be read together; a large quantity of slag for New Plymouth comes through Wellington Port.

Concerning the relative merits of slag and superphosphate, it is interesting to note that New Plymouth imports more slag than superphosphate, and this disproportion will probably be much greater in future years, the Taranaki climate being exceedingly moist and the soil responsive to slag treatment. At Napier, on the opposite coast, the port for the Hawke's Bay District, the climate and soil of which are much drier than those of Taranaki, and the country often calcareous —conditions favouring the use of superphosphate—the imports of superphosphate are more than twenty times greater than those of slag. The same is true of the even drier climate of Canterbury (Lyttelton and Timaru ports).

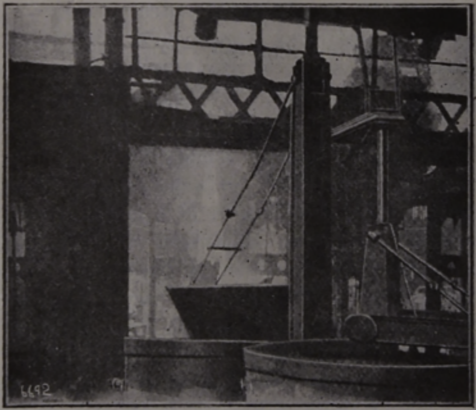
Great Britain is the only country in Europe in which the production of Thomas's slag largely exceeds the consumption. Thus, in

THE CONVERTER TURNED UP, WITH THE "BLOW" IN OPERATION.

1899, more than half the total output was exported to different countries, chief of which were Germany, which took 34,000 tons, and France, 30,000 tons.

The world's consumption of slag was, in 1906, estimated in round figures at 2,500,000 tons annually, of which Germany used 1,300,000 tons, and the United Kingdom only 170,000 tons. The average consumption per acre of grass and tillage land is, in Germany, 32 lb., in the United Kingdom about 8 lb. As a possible correlative of this fact, it has been pointed out that the yield of grass in Germany has increased nearly 20 per cent. since the application of basic slag became general in that country, where, it may be added, about one-half of the phosphoric acid used in field-manuring is applied in the form contained in basic slag. In Great Britain slag did not begin to be used to any extent until 1894.

It is interesting to note the effect which the advent of the basic process—so called from the fact of the preponderating use of the alkaline or basic materials (lime, magnesia, and iron-oxide) in the manufacture—has had on the production of steel. According to Storer 85 per cent. of the known deposits of iron in Great Britain are contaminated with more than one part of phosphorus per thousand When the ores are smelted practically the whole of the phosphorus remains in the pig iron, and it was a matter of no little difficulty to convert such pig iron into steel, as the pigs contained from 2 per



THE CONVERTER TURNED DOWN AFTER THE "BLOW" IS FINISHED, AND THE SLAG BEING POURED INTO THE "LADLE" BELOW.

cent. to 4 per cent. of phosphorus, which, if not removed, would render the resultant steel brittle or "cold short." The basic process has therefore not only enabled low-grade iron-ores to be largely utilized in the manufacture of mild steel, but has proved a method of removing a harmful impurity from the iron and converting such impurity into an extremely valuable manurial constituent. Some idea of the amount of steel produced by the process may be obtained from the figures for slag-production quoted, when it is remembered that for every ton of slag made 5 tons of steel are produced.

Composition.

Basic slag is essentially a mixture of phosphates and silicates of lime, magnesia, manganese, and iron, together with small quantities of other compounds of minor interest. All the main constituents vary within certain limits, with one exception—lime—which is always constant within relatively narrow limits.

The following complete analyses* show the manner in which the composition may vary :—

	K153.	K376.	K842.	
Loss on ignition	0·85	2·40	..	..
Silica	10·32	14·50	18·90	7·38
Iron-oxides..	12·50	17·46	15·81	22·16
Phosphoric anhydride	18·85	10·52	8·55	14·36
Lime (CaO)	46·40	43·66	44·00	41·58
Alumina	2·15	2·40	2·60	2·57
Magnesia	3·90	4·60	4·33	6·14
Manganese-oxide	4·20	3·65	4·80	3·79
Sulphuric anhydride .. .. .. } Calcium .. .. }	..	..	..	0·31
Vanadium-oxide	..	..	..	1·29
Sulphur	0·80	1·23	1·01	0·23
Solubility of phosphoric anhydride in 2 per cent. citric-acid solution	15·50	8·95	4·44	..
Fineness (percentage passing through sieve of 10,000 meshes per square inch)	76·00	86·00	59·00	..

Although slag varies so much in composition its aspect to most of the senses is unvarying. Certainly to some extent one might become expert at roughly judging the fineness of a sample by the sense of touch but there is no fertilizer concerning which so little may be learnt by a hand-and-eye examination as basic slag. This fact may account to some extent for the cautious way in which the British farmer has received an article which has no smell or taste, and which looks and feels like so-much fine grit. His preconceived notions of a strong fertilizer are that it should certainly smell, taste, and look strong. "You wouldn't think it to look at it" was a farmer's comment recently on a successful application of slag to pasture.

Experiments have shown that the efficacy of basic slag is directly proportional to the quantity of the total phosphate of lime which is soluble under certain conditions in a 2-per-cent. solution of citric acid. Citric acid as a solvent for slag has, however, only in recent years (1906) been recognized by regulations under the Fertilizers and Feeding Stuffs Act of Great Britain. This solvent is not yet recognized by the New Zealand Fertilizers Act, 1908, which was framed upon the British Act two years before the regulations appeared.

* The above analyses were performed in this laboratory except the last, which is the oft-quoted one by Stead and Ribsdale (Iron and Steel Inst. Jour., 1887, p. 22).

The phosphoric anhydride in basic slag was supposed by some to exist wholly in the form of tetracalcium phosphate, in which four atoms of calcium are contained in the molecule; certainly investigators have isolated crystals of the composition stated.*

For the sake of comparison the kind of phosphate found in phosphatic fertilizers may be stated:—

(1.) Monocalcium phosphate (in "superphosphate of lime" is $CaH_4(PO_4)_2$, or $CaO, 2H_2O, P_2O_5$—one atom of calcium in the molecule.

(2.) Dicalcium phosphate (in "reverted phosphate") is $Ca_2H_2(PO_4)_2$, or $2CaO, H_2O, P_2O_5$—two atoms of calcium in the molecule.

(3.) Tricalcium phosphate (in "bone phosphate of lime") is $Ca_3(PO_4)_2$, or $3CaO, P_2O_5$—three atoms of calcium in the molecule.

(4.) Tetracalcium phosphate (in "slag phosphate") is $Ca_3(PO_4)_2$, CaO, or $4CaO, P_2O_5$—four atoms of calcium in the molecule.

Fineness.

All authorities agree that a most important factor in the success of a slag is its fineness; but that it would be extremely misleading to rely on this character alone is shown in the analyses of samples in the Department's laboratory. No. K208, which has a fineness of 91 per cent., is a low-grade slag, deficient both in available (citric soluble) and total phosphoric anhydride. On the other hand, No. K513, which has a fineness of only 70 per cent., is one of the best slags on the market in other respects. Wagner's experiments, indeed, show that, after a certain fineness has been obtained, no better results are obtained by further grinding, and that a slag which all passed through a gauze sieve (250 wires to the linear inch) was not superior to one which left 17 per cent. behind, and which therefore had a fineness of only 83 per cent.

Carelessness in manufacture often results in the slag containing comparatively large irregularly shaped pieces of steel—a positive fault in a slag, for not only are such slags difficult to distribute, and lead to loss of much time and temper in keeping the manure-box running clear, but they may be productive of injury to the farmers' drills.

Purchasers of slag must therefore be guided entirely by the chemist's analysis, and it is only after some hours' work that even he can say whether a sample agrees with the guarantee.

* Hilgenstock, June, 1886, *et aliis*. Stead and Ribsdale—J. C. S., 1887—state that the whole of the P_2O_5 is in the form of tetracalcic phosphate. Wiley, "Fertilizers," states that in all good slags the lime and P_2O_5 will be found combined in this form. A. D. Hall, "Fertilizers and Manures," 1910, considers it more probable that the typical phosphoric-acid compound of basic slag has the formula $(CaO)_5$, P_2O_5, SiO_2 rather than $(CaO)_4$, P_2O_5—that is to say, it is a compound of lime with phosphoric and silicic acids.

How to buy Slag.

There are three points to consider in buying slag—(1) The total percentage of phosphoric acid (phosphoric anhydride); (2) the proportion of this which is soluble in a 2-per-cent. solution of citric acid when treated in a specified manner; (3) the fineness. A good article should contain from 16 per cent. to 24 per cent. total phosphoric anhydride, of which at least 80 per cent. should be soluble in 2 per cent. citric acid. From 75 per cent. to 90 per cent. of the slag should pass through a standard sieve. The sieve recommended by Wagner and generally adopted in specifications is the one numbered 100E, made by Amandus Kahl, of Hamburgh, which contains 100 wires to the linear inch.

In buying slags, or, indeed, any fertilizer, purchasers must not be misled by the alternative use of the terms "phosphate" and "phosphoric acid" into believing that these terms are synonymous, for tricalcic phosphate only contains less than one-half its weight of phosphoric anhydride—usually, but not quite accurately, called "phosphoric acid."* A slag containing only 8 per cent. of the anhydride may be sold with truth under a guarantee of 17 per cent. tricalcic phosphate; and the purchaser, deluded by the similarity of the figure "17" to the percentage of phosphoric anhydride usually found in a good sample of slag, buys it at a high figure, only to find that he has been misled through his want of knowledge.

One part of phosphoric anhydride (P_2O_5) is equivalent to 2·183 parts of tricalcic phosphate; conversely, 1 part of tricalcic phosphate is equal to 0·458 part of phosphoric anhydride. If a purchaser wishes to know what a certain amount of phosphoric anhydride is equal to in tricalcic phosphate, he has only to multiply figure of the former by 2·183—or, what is probably near enough for his purpose, 2·2 ($2\frac{1}{5}$). To transform tricalcic phosphate into phosphoric acid he must multiply by 0·458.

ITS APPLICATION.

Use of Slag for Root Crops.

While for top-dressing pasture on clay lands basic slag is usually applied unmixed with other fertilizer, and for lighter lands sometimes with a slight admixture of potash salts, for crops such as turnips, mangels, rape, and potatoes, when it is intended to use slag, it will

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* What is meant by "phosphoric acid" in the fertilizer trade is the anhydride of the acid (P_2O_5), which is phosphoric acid from which water has been abstracted.

$$\underset{\text{(phosphoric acid)}}{2H_3PO_4} \quad - \quad \underset{\text{(water)}}{3H_2O} \quad = \quad \underset{\text{(phosphoric anhydride).}}{P_2O_5}$$

be better to mix it with an equal quantity of superphosphate or other fertilizer. Superphosphate and slag mixtures have given excellent results with root crops, enhancing both the quality* as well as the quantity.† This was when the amount of phosphate was applied very much in excess. One would like to see in experiments with which only the usual amount of phosphate is applied whether slag and superphosphate would prove superior to an equal quantity of superphosphate alone. The experiments should be continued over several years to minimize the seasonal variations. In a dry season superphosphate has proved inferior to slag, and in a wet season superior, the acid nature of the superphosphate when undiluted by sufficient soil-water being, no doubt, especially injurious to the young seedling. The mixing of slag and superphosphate has not received the sanction of all authorities; and no doubt some intelligence is required to be exercised in using this mixture, as, when left for a little time, it sets to a hard, refractory mass. The farmer must therefore be careful not to mix up more at a time than is sufficient for his immediate needs, and if any of the mixture is left over he must clean out his drill thoroughly. Of course, it is open to him to add sufficient inert matter, such as sand, gypsum, peat, or dry earth, to the mixture to retard its chemical action, and so prevent the setting. On soils very rich in humus and deficient in mineral matter, such as those resulting from the drainage of some swamps, basic slag will, no doubt, prove superior to superphosphate or mixtures of the two when drilled in with the seed. This type of soil is usually deficient in potash, which must be supplied with the slag, especially when attempting to grow potash-loving crops like the mangel or potato.

As a Dressing for Pasture.

It is to the effect of basic slag on pasture that the attention of the New Zealand farmer will be most profitably directed. In order that the application of slag shall be beneficial, the soil and climate must conform to certain conditions necessary to success.

(1.) In the first place, since slag is essentially a phosphatic fertilizer, the soil must be in need of phosphate, or, as the chemist would say, it must be deficient in available phosphoric acid. At Cockle Park, in England, where the use of slag was very efficacious, the soil was deficient in phosphates. In some Scottish experiments where slag

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* Forty sheep fed on slag-grown turnips made nearly 15 per cent. more increase than forty treated in exactly the same way but fed on superphosphate-grown turnips (West of Scotland Ag. Coll. Reports, 1901, p. 50).

† G. Gray ("Retrogression of Soluble Phosphates in Mixed Manures," Aust. A. A. of Science, 1904 Rept., p. 159) has shown that when equal quantities of slag and superphosphate are mixed, although the water-soluble phosphate is quickly rendered insoluble in water, the total amount of phosphate which is soluble in citrate solution and is therefore readily available as plant-food undergoes little change during eighteen days.

failed to produce the great and rapid improvement produced at Cockle Park it was found that the soil contained an amount of phosphate from three to ten times greater than that of the English farm (West of Scotland Ag. Coll. Report, 1911, p. 38: Somerville, p. 4). As most New Zealand soils are deficient in phosphates this condition may generally be assumed to be satisfied.

(2.) Basic slag is an alkaline fertilizer containing an excess of caustic lime, hence soils which are already alkaline in reaction due to the presence of carbonate of lime would probably receive more benefit from superphosphate—an acid fertilizer—than from an equivalent quantity of slag. Most of our soils are, however, deficient in carbonate of lime, and are acid or sour, so that this condition is usually favourable to the use of slag.

Photo by B. C. Aston.

The Field on the Left-hand Side of the Picture was Top-dressed with Basic Slag. The Field on the other Side of the Fence received no Phosphatic Dressing.*

(3.) As a top-dressing for pasture, in order to be beneficial, slag requires a climate with a well-distributed rainfall, slag being only slowly dissolved by water containing carbonic acid; whereas superphosphate is entirely and quickly dissolved by pure water. A moist climate is therefore a prominent factor in the successful use of slag; if deficient in phosphates, soils in dry climates with few rainy days are better treated with superphosphate.

(4.) Sandy soils are considered to be not so responsive to slag as are clay soils, nevertheless the herbage on the coarse sandy pumice soils of the North Island is greatly benefited by slag, although superphosphate more quickly shows beneficial results.

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* The illustration shows the great effect produced by basic slag on the poor pumice sandy soils of Lichfield, near Putaruru.

(5.) The greatest immediate effect of slag is manifested on the leguminous (clovers, &c.) components of the pasture, the white clover (*Trifolium repens*) being especially benefited. It is therefore necessary that these plants should be present in the pasture. Experiments with slag in Scotland, Professor Patrick Wright ("Improvement of Poor Pastures," p. 10) tells us, failed owing to the absence of clovers in the pasture. When, however, clover-seed was supplied the effect of slag on these soils was quite as remarkable as on those of Cockle Park.

There are several other important points regarding the application of slag which may be briefly touched on; but in discussing the subject it must be borne in mind that the conclusions arrived at and the advice given must not be considered infallible. It should be clearly understood that these are supported by certain evidence, and are no doubt true for the conditions under which the experimental evidence was originally obtained. All of these conditions may not be known and others may be unattainable: hence the difficulty in drawing from experiments conducted in the Northern Hemisphere conclusions which shall help us in New Zealand.

In England it has been proved more profitable to apply a heavy dose of basic slag as a single dressing than to divide it into two equal portions, and to apply these with a three-years interval (Somerville: "Influence on the Production of Mutton of Manures applied to Pasture,"* 1911, p. 57). In New Zealand, at Waerenga, Waikato, 1911, the aggregate yield of green grass per acre for the four years on a paddock which had been dressed with half a ton of slag on one application was 22½ tons, whereas where the same quantity of slag was distributed over the four years in four annual dressings the aggregate yield was only 10¾ tons (Dept. of Ag. Ann. Rep., 1909, p. 352). The following results were obtained:—

Plot.	Manure (Uniform Cost, 15s. per Acre per Annum).	Yield of Green Grass per Acre.			
		1905.	1906.	1907.	1908.
		lb.	lb.	lb.	lb.
1	No manure	520	620	720	1,500
2	10 cwt. basic slag, 2 cwt. kainit, applied 1905	6,900	9,275	7,780	8,800
3	10 cwt. basic slag, applied 1905	7,390	15,110	14,440	13,600
4	373 lb. basic slag, applied annually ..	2,010	4,860	10,020	7,200
5	2 cwt. 2 qr. 14 lb. super., applied annually ..	3,680	8,515	9,300	9,100

In these results the increase in yield on the untreated plot is noticeable. The stock grazed across the plots no doubt distributed a greater amount of phosphates on No. 1 plot than they would otherwise have done had there been no greater excess of phosphate in their food than usual.

* Every grazier should obtain this (price 4d.) from the British Board of Agriculture.

It is to be regretted that it was not possible to continue these experiments a few more years, in order to ascertain how long the good effects of slag would have been produced with such intensity. In England the effects of slag were not nearly exhausted at the end of nine years. The Waerenga soil was a stiff clay deficient in carbonate of lime and containing only traces of available phosphate, but having a considerable excess of available potash. The rainfall was from 50 in. to 60 in., falling on 190 days. Clovers were present in good amount, and the effect of the slag was most marked in increasing the clovers. This could not be attributed to the action of the lime in the slag liberating potash from the clay, as that fertilizer was already present in amount more than sufficient.

Clovers increase the amount of nitrogenous organic matter in the soil; and when they decrease in quantity, as they do in a few years, the soil is left in a much better condition for the growth of grasses, which are greatly benefited by the increased nitrogen and the better mechanical state of the soil due to the additional humus. A dressing of potash at this stage is often beneficial. Some experiments lead to the conclusion that, even after a heavy dressing of slag has been applied, further applications are often profitable.

There is some evidence that the conditions in New Zealand are much more favourable than in England to the use of slag. One need only point to the quicker action of slag here, the smaller quantity which produces positive results, its beneficial action on some coarse sandy soils, and the unusually good effect of the coarse particles of slag (Aston, "On the Manuring of Pastures in New Zealand") in support of this statement. At the same time it must be remembered that there are undoubtedly large areas in New Zealand to which slag is unsuited. This is an aspect of the subject on which it is hoped to publish further definite geographical advice in the future.

In valuing the effect of slag it must be remembered that, apart from the enhanced quantity of growth produced, the feeding-quality is greatly improved. In a field an unfenced portion of which has been dressed with slag, the stock may be found to graze on this so heavily that the pasture is "eaten out." An unobservant experimenter, on inspecting the plots, might then fall into considerable error regarding the efficacy of slag.

As an example of the effect of basic slag on poor soil, the following is given me by Mr. R. W. Roche, who obtained the information on the spot from a Raglan farmer. This gentleman asserts that he has some land which is so poor that it will scarcely grow fern (*Pteris aquilina*), or tea-tree, or manuka (*Leptospermum scoparium*). Vitriolized bonedust at the rate of 4¾ cwt. per acre was first tried, but there was no result. (Note.—This would cost about £1 15s. per acre.) A couple of years after he top-dressed with 4 cwt. basic slag (costing about 18s. per acre), and the effect was very marked; the herbage, especially trefoil, thickened out. About two years after —August, 1911—he top-dressed with about 2 cwt. superphosphate, and in October, 1912, he gave another top-dressing of slag. He now says he has as fine a paddock of good pasture as could be desired. A neighbour grew potatoes two years in succession on the same piece of ground. He manured with 5 cwt. basic slag alone. The first year he got 11 tons of table and seed potatoes to the acre; the second year, with the same dressing of slag, he obtained 13 tons of table and seed potatoes per acre.

I have quoted these instances fully in order to show that practical farmers may be fully justified in using large quantities of phosphatic fertilizers within a comparatively short period of time on some of the quick northern soils of this Dominion. It may, perhaps, enhance the value of this information to some if it be added that the above examples are taken from ordinary farming practice and are not the results of co-operative or State farm operations. In the first instance we have a probable expenditure for manures for the five years of, say, £3 10s. per acre; in the latter case of, say, £2 per acre for the two years.

The Waerenga experiments seem to indicate that for pasture the fertilizer is better applied in one dressing than in several smaller dressings over several years.

BASIC SLAG - SUPERPHOSPHATE MIXTURE.

Top-dressing Pasture.

I drew attention on page 312 of the September, 1913, number of the *Journal of Agriculture* to the use of basic slag and superphosphate mixture on pumice soils. The difficulties in connection with mixing and distributing the mixture are such that it is advisable to have an alternative method of procedure which retains the features of the mixture while disposing to some extent of the difficulties. This is effected by distributing the slag first and the superphosphate subsequently, but as soon as possible afterwards. It is desirable that the basic slag should be applied before the superphosphate, instead of working in the reverse order. The advantages of the mixture may be attributed to the constituents of the two fertilizers working in conjunction, and hence it is advisable that they should come into contact in the soil. The slag is insoluble in water, but the superphosphate is soluble—hence it is easy to see that the superphosphate has a better chance of coming into contact with the slag if the superphosphate is on top.

Whether the application of the two fertilizers singly to a pasture will be as efficaceous as if they were mixed before distribution is impossible to predict without the knowledge that exact experiments will give; but one can at least say that there is every indication of the mixture proving superior to the individual constituents applied alone in the same quantity to the light northern soils which respond to phosphates.

The mixing of basic slag and superphosphate in the treatment of pumice pasture lands which has been followed on my recommendation has given remarkable results, and is likely to prove the best dressing for pumice country of that class. One experiment was inspected in which (1) 4 cwt. slag, (2) 4 cwt. superphosphate, and (3) 2 cwt. slag and 2 cwt. superphosphate were applied to three different paddocks. The last-named has given the best-looking pasture, and cattle allowed the range of the three paddocks showed a great liking for that dressed with the mixture.

Drilled in with the Seed.

It is well to call attention to the good results which have followed the application of basic slag and superphosphate mixtures to turnip crops. Mixtures of 2 cwt. basic slag and 1 cwt. superphosphate per acre, drilled in with the seed, have given excellent results, even when the mixture has heated after mixing. A mixture of bonedust, superphosphate, and basic slag in equal parts should be experimented with, taking care to mix only small quantities at a time. Theoretically such a mixture should be a good one, as the bonedust should improve the mechanical state of the fertilizer, enabling it to run through the drill more easily, while the acid nature of the superphosphate should prevent the alkaline basic slag from reacting with the nitrogenous matter of the bonedust, and consequently preventing the loss of ammonia which otherwise might result.

Conclusion.

In conclusion, it may be pointed out that possibly there is much yet to be learnt as to the action of slag. There is one constituent of slag that does not occur in other artificial fertilizers to any extent —viz., iron—and iron compounds are known to exert a beneficial influence on the bacteria of the soil, especially the azotobacter—the organisms which fix the nitrogen of the air.

It is difficult to condense all one would like to say within the compass of a Bulletin, but it is hoped that some of the leading facts with regard to slag have now been made more clear to the farmer, and that he will realize the great possibilities of slag as a factor in the improvement of his pasture.

Note.—I am indebted to the *Mark Lane Express* for the figures relating to the use of slag in Europe, and to Alan Murray's excellent book for the illustrations of the Bessemer process.

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