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LIMING SOIL

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1/ Includes five articles on value of liming in US attached herein.

Liming Soils

Lime was applied as a soil amendment in ancient times, long before the Christian Era, and the same factors which created lime-deficient soils at that time are still operating today. Soils in humid areas will always be affected by these lime-depleting processes.

A Virginia farmer named Edmund Ruffin (1794-1865) was probably the first man in the United States to sense the prevalence of acidity and the need for lime in soils of Eastern United States. Since this time much experimental work has indicated definitely that liming is an important practice in scientific soil management. The liming of acid soils should be accepted by all as a fundamental and essential practice; it is frequently referred to as the "backbone" of permanent agriculture in humid regions.

A. The Need of Soils for Lime

Certain soils have developed from rocks and minerals which in themselves were naturally acid. Those rocks which contain more quartz or silica than basic constituent are known as acid rocks. Soils derived from such materials are acid even though no loss of bases may have taken place during the formation. Most acid soils, however, have developed as a result of leaching losses and crop removal of bases.

The functions of lime in soils are numerous and result in their improvement and increased crop production. Since soils may vary greatly in their physical, chemical, and biological properties, it is not to be expected that a lime deficiency will produce exactly the same unsatisfactory conditions in each case and, as a result, some soils may give a much greater response to lime than other soils. Injurious effects may result from the use of lime under certain conditions especially when applied in excess.

The major important functions of lime in the soil may briefly be given as follows:

1. Neutralization of soil acid.

Lime in the forms of oxide, hydroxide and carbonate reacts rather rapidly with moist, acid soils. The reactions of these forms vary somewhat, but the final result is the same. In other words, the process of neutralizing acid soils is the reverse of that by which they become acid.

2. Influence of calcium on plant growth.

Calcium is an indispensable element for the growth of all crops. Many soils are too low in lime content to supply the needs of crops, especially certain species of leguminous plants.

The nutritive value of animal feed is to a large extent influenced by the calcium content of plants. That lime should be present in sufficient quantities in all properly balanced livestock rations is now an accepted fact. The importance of the calcium content of food for growing children and for treating certain types of human disease is well recognized by physicians.

3. Effect of lime on the solubility of soil nutrients.

As a general rule, a relatively high percentage of the phosphorus in soils well supplied with lime is available for plant use and the phosphorus of calcium-deficient acid soils is in relatively unavailable forms even though the total phosphate content is comparatively high. Soil phosphorus is generally most readily available to plants in neutral or slightly acid soils, and with increasing acidity its availability decreases. In strongly acid soils, in the presence of aluminum and iron compounds, soluble phosphates combine with these elements forming relatively insoluble aluminum and iron phosphate compounds. In alkaline soils in the presence of excess calcium carbonate (about two per cent) phosphorus combines with calcium, forming tricalcium phosphates. This form of phosphorus is of low solubility but is more soluble than the phosphates of aluminum and iron.

Liming acid soils has a tendency to make the phosphate compounds in the soil more available. Increasing the calcium content of soils will convert a part of the phosphorus that is present as aluminum and iron phosphates to the more available calcium phosphates. The more desirable forms from the standpoint of plant use are the monocalcium and dicalcium phosphates.

When soils become deficient in bases, the solubility of aluminum iron and manganese increases. In strongly acid soils, the high concentrations of these elements may be toxic to plant crops. A normal application may prevent toxic concentrations of these substances; yet too much lime may create an iron and manganese deficiency.

4. Effect of lime on microbiological processes of the soil.

Calcium is closely associated with certain important microbiological processes. The more important effects of calcium on the

soil population may be grouped as follows: (a) promoting the decomposition of organic matter, (b) making conditions favorable for nitrification and sulphofication, and (c) providing favorable conditions for the growth and functioning of both symbiotic and non-symbiotic nitrogen-fixing bacteria. Each group of organisms which contributes to the above processes functions most efficiency in soils well supplied with lime. In many of these processes, it is not necessarily a matter of changing the pH but one of supplying soluble calcium.

Lime may be used as a preventive of certain types of plant diseases which occur only in acid soils. However, an alkaline soil, caused by the use of too much lime, is likely to depress certain desirable biological processes, such as nitrification and the decomposition of organic matter. Furthermore, it is generally believed, although it does not always occur, that the application of lime in amounts sufficient to make a soil neutral or alkaline favors potato-scab disease.

5. Influence of lime on the effectiveness of fertilizers and manure.

The full benefits of fertilizers and manures are realized only after ample supplies of lime have been provided. Fertilizers and manures are more effective when all soil conditions are favorable. Seldom do they produce maximum results in acid soils. Lime is not a substitute for fertilizers and manures, but when lime is needed its application will greatly increase their effectiveness.

Nitrogen and potassium of fertilizers and manures are not made insoluble as a result of a lime deficiency, but since crops do not grow so well as in lime-rich soils, the plants cannot utilize the nitrogen and potassium as well as they could if growing conditions were made more favorable by the presence of lime. If nitrogen is applied in forms other than nitrate, the presence of lime will hasten the production of nitrates.

6. Effect of lime on the chemical nature of soil colloids.

Under leaching conditions, the calcium and other bases are gradually replaced by hydrogen ions from the surface of colloidal particles. As these particles become more acid, they tend to become more chemically unstable. The remedy for this is lime. Not merely does it act as a neutralizing agent but also it restores calcium on the soil particles, producing significant effects on various chemical as well as physical and biological properties of the soil.

7. Effect of lime on soil structure.

The replacement of calcium ions on the soil colloids with hydrogen ions results in the production of a dispersed condition of the colloid. If these dispersed colloids are carried downward in the profile, dense subsoil horizons may gradually develop. But as long as the colloids remain essentially saturated with calcium, dispersion will not occur.

A soil with high content of lime is more likely to remain in good tilth than one low in lime. This is especially observed in heavy soils. The presence of sufficient lime aids in making soils loose and friable, permitting better aeration, assisting in drainage and is important in plowing and seedbed preparation.

Lime may affect the physical properties of the soil indirectly by regulating to some extent the kind and amount of organic matter returned to the soil, the rate of decomposition and the nature of the humus that is formed.

B. Soil Reaction

Soils may be acid, neutral or alkaline in reaction. The reaction of soils is significant in crop-production and soil management practices because the various degree of soil reaction are produced by the chemical conditions which exist in soils, each set of chemical conditions causing its corresponding degree of soil reaction. Soil reaction, then, may be considered a symptom of the particular chemical conditions which caused it and hence it may be used to indicate the possible effect of these conditions on plant growth. The degree of soil acidity is therefore probably the most important and useful information to be considered in diagnosing the general fertility of soils and the required lime application for the desired increase in plant growth and field production.

1. Methods for determining soil acidity and lime requirement.

If it is desired to measure the active acidity of a soil, it is necessary to determine the hydrogen-ion concentration. This is the most commonly used measure of acidity both in soils and in many other materials. The most accurate procedure is by the use of an electrode which sets up a potential with the active hydrogen-ions present in the soil.

It may be mentioned, however, that the simple colorimetric tests are sufficiently accurate for practical purposes. It is much more desirable from the practical standpoint to test a large number of samples from a particular field with the simple test than to test only one or two samples by one of the more accurate but time-consuming laboratory methods.

Various dyes which give distinct color shades at different pH values are used extensively, in the laboratory and especially in field kits, for determining pH values with relative accuracy. Different dyes which change color within different pH ranges may be used separately or several of them may be included in one solution.

A test based on the occurrence of soluble iron in acid soils involves the use of a solution of potassium suphocyanate (KSCN). This gives a red color with soluble ferric iron which indirectly represents the degree of soil acidity. It is simple, sufficiently accurate, inexpensive and practical for field testing.

2. Interpretation of results of acidity tests.

Because hydrogen-ion concentration determinations give a measure of active but not total acidity, they must be used in association with other information in estimating the quantity of lime to apply in order to bring a given soil to a desired pH for maximum plant growth.

Soil-acidity tests, together with an understanding of the chemical factors associated with the test results and an understanding of a plant's requirements furnish a basis for making recommendations. Also the quantity of lime recommended for a soil with a given pH is increased progressively as the soils vary from sandy to loam, silt loam, clay loam and clay. Lime recommendations are usually made by experienced workers who have in mind the results of numerous field experiments involving the use of different quantities of lime on different soil types growing various crops.

3. Response of crops to lime.

Crops response to lime depends upon a number of factors, among which the pH of the soil is an important one. It is, however, generally accepted that pH as such is rarely the limiting factor in plant growth within the range normally existing in agricultural soils. Plant growth frequently is retarded in acid soils because of unfavorable chemical conditions associated with low pH; for example, the degree of base saturation is definitely related to pH, and since calcium, magnesium and potassium are all involved, plant growth must be affected by the supply of these elements. The solubility of aluminium, iron, manganese and other minor elements is also related to pH, as are also the activity of micro-organisms, soil chemical reactions and physical conditions. In general, the legumes respond more to lime than the non-legumes.

4. Kind of lime to use.

In selecting the liming material to use, several factors must be taken into consideration which will vary with the conditions attending each individual farmer. The following factors are among those which should be considered in choosing the form or grade of lime that should be used; (1) relative cost of calcium in the different forms, (2) finesses, (3) rapidity of action with the soil, (4) convenience in handling and storing, (5) character of the soil, and (6) crops to be grown.

The carbonate forms of lime are generally more convenient to handle and less disagreeable than the caustic forms, even when the latter are bagged. Furthermore, limestone in storage, if kept dry, will not change form as will the caustic forms. The difficulties is scattering or spreading materials, such as marl and industrial by-products, in the field should be considered in selecting the form of lime to use.

Obviously, on certain soils containing large quantities of magnesium, it is desirable to avoid the use of certain forms of lime rich in magnesium. If the soils are deficient in magnesium, dolomitic limestone, if available, should be used.

5. Quantity and frequency of lime application.

The amount of lime to be used depends primarily on the (1) degree of acidity of the soil, (2) buffer capacity of the soil, (3) acidity of subsoil, (4) crops to be grown, (5) form or grade of lime to be used, and (6) frequency of application.

6. Time of applying lime.

It is advisable, of course, to apply lime where it can be used to the best advantage in the rotation. In general practice it is usually recommended that lime be applied when most convenient since the most important consideration is that of applying it regularly in the rotation as needed. Late summer or fall applications are usually most convenient. At this time of the year, there is a lull in farm work, and the roads and fields are in a good condition for handling and spreading. "Do not put if off (lime the field any time if needed), put it on" is an old but common saying regarding liming.

7. Methods for applying lime.

The principal requirement of any method of applying lime is that it should be distributed evenly and, except when applied to pastures, it should be thoroughly mixed with the soil. Since soil acidity is due largely to the colloidal clay acids, it is essential that lime

comes in contact with all the soil particles so far as possible. This requires a thorough and even mixing of the lime with the soil with tillage operations.

8. Chemical guarantee.

Since the potential capacity of a liming material to neutralize soil acidity is determined by its content of calcium (and/or magnesium) and since these materials are sold on the basis of their soil neutralizing power, chemical guarantees are of great importance.

In most countries having lime control laws, it is customary to state the guarantee of commercial hydrates and oxides in terms of oxide content. This shows the amount of magnesium as well as calcium present, which is an important consideration particularly where magnesium may be needed in the soil. The statement of the chemical analysis in terms of the oxide (CaO) equivalent or in terms of the neutralizing power of calcium carbonate is convenient in that it is made in one figure. Thus the process of comparing the values of different liming materials is quite simple.

The method of stating guarantees for ground limestone is somewhat different from that for commercial oxides and hydrates. The quantities of calcium and magnesium carbonates are usually expressed separately and in terms of total carbonates on a percentage basis. These may be expressed in terms of oxide of calcium (CaO) equivalent, in terms of neutralizing power , or even in terms of elemental calcium and magnesium. A representative sample of ground limestone may be expressed in one or more ways.

Of the various methods of expressing guarantees, the neutralizing power is the easiest and most rapidly determined. From an analytical point of view, this is an important consideration when many samples are involved. Yet the meaning of the carbonate method of guarantee is perhaps easier for the farmer to understand and it gives the quantity of magnesium which is an advantage of this method of presentation. However, the difference between these two values (carbonates and neutralizing power) are usually so small that it is practically of little or no significance.

9. Fineness guarantee.

A fineness guarantee is based on a mechanical analysis of a particular sample of ground limestone made by the use of standard screens of definite mesh or size openings. A ten-mesh sieve or screen, for example, has ten openings per linear inch or 100 openings per square inch. The quantities of stone which will pass through each of the various screens are stated in the guarantee. The following

is an example: 100 per cent through a 8-mesh screen, 50 per cent through a 60-mesh screen, and 40 per cent through a 100-mesh screen.

With all other factors equal, the finer a limestone is ground, the more rapidly it will dissolve and the more thoroughly it can be mixed with the soil. The effectiveness of a ground limestone of a given neutralizing power is determined not only by its rate of solubility but also by its contact with the colloidal particles. However, the finer the stone is ground, the greater will be its cost and the less will be its lasting qualities. Furthermore, a very finely ground limestone is not only difficult to handle but also unpleasant to distribute. Therefore, it is generally recommended that a ground limestone of medium fineness is purchased. Such a grade can be ground rather cheaply and it contains a sufficient quantity of fine material to give immediate effects and a sufficient amount of coarse material to give it lasting qualities. Such a ground limestone would be one in which all would pass a 10-mesh screen and 30 to 50 per cent would pass a 100-mesh screen.

C. Sources of Lime

One reason why calcium compounds rather than other chemical compounds are used for liming purposes is that there is a plentiful supply of calcium compounds and that they are widely distributed and not harmful in use. In this connection, mention is made below of the different sources of lime and of the nature and supply of such materials.

1. Limestone.

Limestone is the most important single source of commercial liming material. It is a sedimentary rock formed by the precipitation of calcium and magnesium in water in the form of carbonates. Deposits are widely distributed and it is easy to quarry and grind.

2. Commercial liming materials

The calcium of commercial hydrate, commercial oxide and calcium silicate of the blast furnaces all originally comes from limestone. A very large percentage of the commercial lime that is used for liming purposes is used directly in the form of ground limestone or in some form made directly or indirectly from limestone.

3. Marl.

Marl or log lime is formed by lime which was dissolved from the soil in drainage water and carried to the swamps, lakes and other bodies of water where it was thrown out of solution. Marl may be covered by a few inches or several feet of muck or found on dry land where an old lake has been drained by a change in the drainage level.

The purity of marl may vary considerably, even within the same deposit. A marl containing a rather high clay content is very sticky when wet and becomes very hard and lumpy when dry; furthermore, it is difficult to handle and cannot be applied to a soil uniformly.

4. Sugar-factory lime.

In the manufacture of beet sugar, limewater is used. On a dry basis, sugar-factory lime will usually test about 80 per cent calcium carbonate. Owing to its variable moisture content, it, like marl, is usually handled on the cubic-yard basis.

When Korean grain sufficiency is obtained and crop diversification by farmer choice has been developed, sugar-beet farming may be profitable and lime from the factory should be an available by-product at a low cost.

5. Wood ashes.

In certain localities wood ashes may be available in sufficient quantities for use on the soil. The composition will depend not only on the composition of the original wood but also on the completeness of burning, leaching that has occurred and impurities with which it may have become mixed. Wood ashes may be expected to contain 20 to 50 per cent of lime, expressed as calcium carbonate. They will contain about five per cent or less of potash and a very small amount of phosphorus but are usually regarded as more important as a liming material than as a source of potash.

6. Blast-furnace slag.

Slag is a by-product in the smelting of iron ore and is in the form of calcium silicate. This may be considered as a liming material inasmuch as it supplies active calcium, leaves no objectionable residue and has the ability to reduce soil acidity. Basic slag is an important carrier of phosphorus.

7. Chalk, marble, coral and shells.

Chalk, marble, coral and shells also contain lime in the carbonate form in varying proportions. Calcium carbonate is only slightly soluble in pure water; but if the water is saturated with carbon dioxide at ordinary temperature, it is soluble to the extent of about one part by weight in 1,000 parts f water, forming calcium bicarbonate [$Ca(HCO_3)_2$]. Clean oystershells contain about 90 to 95 per cent of calcium carbonate. When finely ground, they are a very satisfactory liming material which is used to some extent on farms located near the source of supply. Oystershell lime sometimes is burned and used in the calcium oxide form.

D. Effect of Liming on General Crop Yields.

Several factors influence agricultural production, among them land, labor and output per acre. Since Korea has little additional land which can be developed economically for agricultural purposes and has some 80 per cent of total employed persons working in agriculture, an increase in yield per acre must be the key to higher production.

Generally there are two methods of raising the yield per acre: (1) adoption of new and improved cultural practices and (2) intensification of capital input. Improved cultural practices include multiple cropping, where possible, and the use of improved varieties, soil improvement crops, soil conservation practices, better cropping systems, lime, fertilizers, controlled irrigation, pesticides and improved seeds.

Korean farmers traditionally have used farm-yard manure, night soil, fuel ashes and compost on their fields. The amount of each has been insufficient. Usage of fertilizer in Korea has increased nearly three times since the pre-World War II era and is now in third place in the Far East; behind Japan and Taiwan. The relationship of the increased yields from the increased use of fertilizers in South Korea is poor.

As a large percentage of the Korean soils are quite acid, this soil acidity may be one of the major causes of the low response from the use of fertilizers.

Fertilizer studies in numerous places in the humid areas have given different ranges of yield increases. In a 12-year study in Tennessee barley yields were increased 11.3 bushes per acre by liming over the same fertilizer applied alone. Limed soybean yields increased 14.2 bushels per acre in a three-year study.

In North Carolina a four-year study showed a return of $55.87 for every dollar spent for liming cotton. Returns per acre for peanuts, soybeans and ladino clover were $45.10, $6.95 and $27.35 respectively.

Acid soils restrict the growth of many crops. Liming should be considered very important in improving the productivity of all cultivated soils. Acid soils should be limed as needed, regardless of crops. However, some farmers are not properly educated to use lime. Because lime is comparatively inexpensive, its value often is underrated by the farmer. On one point, all the experts agree. We must expand our educational program on liming. Of all agricultural programs, none is more important. Until a farmer knows that adequate liming is the starting point for a sound and efficient farm management program and acts on this knowledge, the work is not done.

See the attached papers on the value of liming, lime effects on availability of soil nutrients and added fertilizers, effects of acidity on

different plants, etc. reprinted from "Plant Food Review" - a publication of the National Plant Food Institute, Washington, D.C.

1. Why Don't Farmers Use Enough Lime? Russell Coleman, Executive Vice President, National Plant Food Institute.

2. Lime For More Efficient Farming. Byron T. Shaw, Administrator, ARS/USDA.

3. Liming Is Urgent In The Midwest. Emil Truog, Emeritus Professor, Department of Soils, the University of Wisconsin.

4. To Boost Lime Consumption There Is No Substitute For Promotion. J.W. Fitts, Head, Department of Soils, North Carolina State College.

5. Liming Facts And Figures. Comments from staff, National Plant Food Institute.

6. Better Farmers Use Enough Lime. N.C. Brady, Head, Department of Agronomy, N.Y. State College of Agriculture, Cornell University.

7. Spare The Lime and Spoil The Farm, Clarence M. Wilson and Fred Adams, Soil Chemist and Associate Soil Chemist, Department of Agronomy and Soils, Alabama Polytechnic Institute.

8. Challenge For Tomorrow. Robert N. Kock, Executive Secretary, National Agricultural Limestone Institute.

E. Korean Crop Yield Levels.

Many soil types in Korea are very acid and eroded. There are reasons to believe that many of these soils can be restored by erosion control measures and raised to a much higher productivity level with the use of suitable liming and fertilizer materials.

The crop-yield levels of Korea are low. This is indicated by the following data for the year 1964:

Crop	Planted area (tanbo)	Yield per tanbo (kg)	(suk)	Total production (M/T)	Approx. yield/area (pound)	(bushel) 1/
Barley (covered)	5,035,018	90	0.859	450,542	810	17.6
Barley (naked)	4,015,935	112	0.812	451,212	1,008	16.6
Wheat	1,472,900	93	0.674	136,675	837	13.8
Rye	300,704	56	0.451	16,762	504	9.2
Misc. cereals	2,193,371	57	-	125,650	513	-
(1) Millet	1,383,312	54	0474	75,058	486	9.7
(2) Millet (barnyard)	13,930	21	0.292	299	189	6.0
(3) Millet (glutinous)	25,707	35	0.324	903	315	6.6
(4) Sorghum	161,738	48	0.364	7,817	432	7.5
(5) Corn	432,481	80	0.593	34,712	720	12.2
(6) Buckwheat	176,203	39	0.400	6,861	351	8.2
Rice (non-glutinous)	11,428,355	246	2.460	2,805,970	2,214	50.4
Rice (glutinous)	485,003	211	2.110	102,364	1,899	43.2
Soybean	2,835,084	57	0.423	162,857	513	8.6
Vegetables		M/T				
(1) Root	500,365	1.243		622,121	2,740	-
(2) Leaf	379,952	1.348		512,116	2,971	-
(3) Fruit	309,039	0.767		237,114	1,690	-

1/ Calculated on basis of one suk is equivalent to 5.119 bushels.

Data complied from 1964 Korean Food Crops Statistics, MAF.

The following statement was taken from the TVA Evaluation Team Report entitled "Mixed Fertilizer Plant for Korea", September 6, 1963.

"Need for Lime: Another agricultural problem in Korea is the general acidity of the soils. This is a matter of major concern to MAF and USOM, and an active program is under way to increase lime application. The evaluation team considers this to be an essential adjunct to the mixed fertilizer project, since the fertilizer will be much more effective if soil acidity is adjusted properly before fertilizer is applied.

Data gathered by the Office of Rural Development of MAF on soil acidity in Korea are shown in the following table.

Acidity of Korean Soils

Province	Number of soil samples	Area tested chongbo	Average pH value	pH distribution, per cent of samples in range indicated: Below 5.0	5.0-5.5	5.5-6.0	6.0-6.5	6.5-7.0	above 7.0
Kyonggi-do	1,316	400.7	5.65	5.39	41.62	37.86	11.60	2.25	1.28
Chungchong-pukdo	716	195.2	5.64	7.79	31.17	39.62	14.86	4.64	1.92
Chungchong-namdo	951	293.5	5.50	11.34	43.36	28.67	9.18	4.75	2.70
Cholla-pukdo	946	299.5	5.35	16.35	54.82	20.24	5.01	2.42	1.16
Cholla-namdo	1,421	362.6	5.27	21.77	53.54	16.18	4.61	2.12	1.78
Kyongsang-pukdo	1,812	430.3	5.41	16.01	41.62	28.77	9.62	2.60	1.38
Kyongsang-namdo	1,444	288.2	5.35	16.22	50.45	23.48	7.79	1.80	0.26
Kangwon-do	804	222.6	5.76	1.14	32.26	45.10	14.86	2.77	3.87
Cheju-do	120	26.3	5.67	2.93	27.24	45.07	21.87	2.89	
Average	-	-	5.47	12.58	44.33	29.23	9.40	2.79	1.67

Many of the soils, as indicated in the above table, are so acid that good crop yields, especially for barley, cannot be expected even if adequate amounts of the major fertilizer nutrients are used.

As an example of the value of liming, a barley experiment on upland soil, conducted by the United Nations Special Fund Korean Uplands Watershed Project in 1962, resulted in zero yield when fertilizer was applied but no lime was used. When the soil acidity was adjusted with lime, a yield of 195 kg/tanbo was obtained (N, P_2O_5 and K_2O application was the same on both tests). This yield is twice the average in Korea.

It is estimated that a basic application of 4,000,000 to 5,000,000 tons of lime is needed to adjust the acidity of Korean soils to a desirable level (pH of 6.0 to 6.5). This is equivalent to about two tons per acre. Moreover, a maintenance application of about 1,000,000 tons per year would be required to maintain the desired pH. The magnitude of such an operation is evident from the fact that about 100 freight cars per day would be required for maintenance appplications alone. Neverthless, the need is an important one. It is highly desirable that the liming program be continued and expanded as a means of realizing the full value of mixed-fertilizer production".

"On the basis of published information* concerning pH levels of Korean soils, response to lime in certain experiments and demonstrations, and results on similar soils in U.S., it may be assumed that the efficiency of added fertilizers and manures and crop production in general, is seriously limited by lack of adequate lime on 75% of the upland-cropped area, 60% of the lowland doubled-cropped paddies, and 20% of the lowland single-cropped paddies. In reality, many of the lowland paddies may have lower average pH values (stronger acidity) than upland fields, but the relatively lower lime requirement of rice, higher exchangeable calcium and magnesium contents of paddy fields and higher lime requirements of most upland crops may necessitate more extensive lime needs on the uplands and double-cropped paddies than on the low lying single-cropped paddies.

Since the correction of unfavorable soil conditions caused by the need for lime is essential for optimum soil conditions which markedly affect the efficiency of chemical fertilizers and organic manures, the ultimate success of any soil fertility improvement program depends upon a concomitantly effective and adequate liming program, particularly under the "acid agriculture" of Korea. The effectiveness of nitrogen and phosphatic fertilizers, in particular, has been proven to be seriously limited by strong soil acidity such as apparently occurs commonly in Korea.

The estimated agricultural limestone needs are outlined in the following table. For the total area requiring lime, it is assumed that an average application rate of 4.4 M.T/chungbo (2 tons per acre) of agricultural grade ground limestone would be sufficient to raise soil pH levels to a desirable range.

* Chai Yung Suk, Acid Soils and Their Improvement.
Suwon Agri. Exp. Station, March 1954.

Estimated Agricultural Lime Needed For Korea

Land use	Cultivated area* chungbo, 1954	Portion of cultivated area requiring lime: Per cent	Portion of cultivated area requiring lime: Chungbo
Paddy, double-cropped	354,400	60	212,640
Paddy, single-cropped	816,240	20	173,248
All upland crops	795,990	75	596,993
Total	1,966,630	Average 50	982,871

Immediate need	Limestone required (metric tons)**
Estimated need of 4.4 M.T/chungbo, or 2 tons/acre on 982,871 chungo	4,324,632
Maintenance need	
Estimated need of 3.3 M/T/chungbo, or 1½ tons/acre on total need area once every 5 years, or on 1/5 of need area (196,574 chungbo) each year.	648,694 annually

Propose develop program to provide up to 1,000,000 M/T per year to meet needs of unlimed areas plus maintenance need for previously limed areas.

* From 1955 Yearbook of Statistics of Ministry of Agriculture and Forestry, ROK, published in 1955.

** Expressed as agricultural limestone, minimum 85% $CaCO_3$ equivalent. Hydrated or burned lime may be substituted as available, or equivalent $CaCO_3$ basis.

In view of the complete lack of properly crushed agricultural limestone in Korea at the present time, it appears that a program of use and lime availability will develop so slowly that the vast needs of the area will be very gradually met. It is suggested that a program be developed toward the use of 1,000,000 M.T. of ground limestone per year through an intensive education and demonstration program.

Limestone applications should be based upon reliable soil chemical tests on each individual field to insure maximum return for its use. Exhaustive agronomic studies have been made concerning the fineness of grinding of limestones in relation to their efficiency in improving crop production on acid soils. In consideration of these studies and the probable economics of agricultural lime usage under Korean conditions, there is little justification for requiring ground limestone finer than 10-mesh size in the initial stages of developing a liming program in Korea. It is suggested that ground limestone be considered suitable for agricultural purposes if 100% of it will pass a 10-mesh screen, and if it has a neutralizing value of at least 85% $CaCO_3$ equivalent, with a tolerance of 2 or 3% on both specifications. If ground limestone should become available to agriculture as a by-product from which portions of the finer material had been removed, a specification consisting of at least two sizes should be used, such as 100% passing a 10-mesh sieve and 50% passing a 100-mesh sieve. Limestone should be evaluated on the basis of total carbonates meeting size specifications above, so as to allow higher prices for better quality lime."

Source: "Fertilizer and Lime Needs in Korea" by Fertilizer Consultant Team, October 31, 1956. Published by ICA. Pages 1-3.

F. Potential Return from Adequate Use of Fertilizer and Lime.

The benefit of adequate fertilization and liming practices in Korea can be estimated by comparing the total cost of the additional fertilizer and lime required to reach adequate production levels with the value of the resulting returns in yield. Such an estimate has been prepared, based on the assumption that yields of paddy rice and barley in Korea could be increased to levels currently being obtained in Japan if the quantities and ratios of nutrients now used in Japan were used in Korea, and if sufficient lime were used to correct soil acidity. Current prices for fertilizer, lime and grain were used. The results are shown below and indicate that the return on the money spent for additional lime and fertilizer is 810 per cent.

Average Cost and Returns per Tanbo on Barley and Paddy Rice

1. Using present Korean fertilization rates

Crop	Expenditure per tanbo N	P_2O_5	K_2O	Total	Value of yield per tanbo
Paddy rice	$1.58	$0.45	0.17	$2.10	$27.50
Barley	1.29	0.78	0.04	2.11	3.44

2. Using present Japanese fertilization rates

Paddy rice	1.80	1.15	0.63	3.58	42.68
Barley	1.47	1.06	0.44	2.97	11.68

3. Increase in cost of fertilizer and added value of yield (present rate vs. Japanese rate)

	Increase in cost of fertilizer per tanbo 1/	Increased value of yield per tanbo	Increase in cost of fertilizer and lime (total acreage)	Increase in value of yield (total acreage)
Paddy rice	$1.48	$15.18	$20,119,000	$173,530,000
Barley	0.86	8.24	11,537,000	83,390,000
Net increase in cost or returns			31,656,000	256,920,000 2/

1/ To this must be added $0.28 for lime necessary to correct soil acidity (initial application of one ton of lime per chongbo plus maintenance application of ½ ton every 4 years.)

2/ Return on money invested in fertilizer and lime = 810 per cent.

"For the two main crops, rice and barley, the nitrogen application in Korea is not far short of that in Japan. However, for phosphate and potash - especially the latter - the rates are much lower. The imbalance and the lower over-all application are reflected in the yields; barley especially falls far short, with a Korean yield only 26 per cent of that in Japan. The other crops, except for fruit, follow a fairly uniform

pattern - less than half as much fertilizer, low phosphate and potash, and about half as much yield".

G. Suggested Limestone Supply Plan for Agricultural Use for CY 1966.

1. Objective:

To improve Korean soils chemically, physically and biologically by the addition of lime and increase the efficiency of added fertilizer materials for maximum crop production.

2. Goal : 750,000 metric ton.

3. Source of funds at present:

Estimated sale price	@₩1,327 per M/T	
a. Governmental subsidy	₩597.15 "	
b. Farmer's cost	₩729.85 "	
Required total subsidy	750,000 M/T @597.15	₩447,862,500.00
1966 budget proposal		₩290,925,000.00
Deficit		₩156,937,500.00
Soil testing estimated expenses		₩ 38,925,000.00
1966 budget proposal		₩ 2,128,000.00
Deficit		₩ 36,797,000.00

If kits and reagents are prepared by ORD, Suwon, to meet village-level needs, budget may be sufficient. This is being investigated further. Four hundred seventy units have been purchased previously. Reagents can be prepared at very little cost.

4. Cooperation for coordinated liming program:

a. MAF responsibilities:

(1) Supervision of the project through administrative channels.

(2) Allotment of funds in ratios to needs of provincial NACF.

b. Provincial duties:

To see that all farmers can obtain limestone to meet their seasonal needs at the lowest cost and at a sufficient and realistic credit rate on a province basis.

The following table gives the estimated limestone needs by provinces for CY 1966 and the available potential in each by known sites. This information may be helpful in studying the feasibility of each province supplying the needed limestone at a lower cost due to shorter hauling distances.

Funds programmed for distribution, transportation, etc. would be handled and directed internally in each province. Thus transportation and other costs would undoubtedly be reduced to the advantage of the farmer.

Also in 1963, and 1964, 1,362,749 and 2,219,658 metric tons of limestone (expressed as CaO) respectively, were mined in Korea. In 1964, 107,266 metric tons (lowest) were mined in February and in November 358,918 (highest). Possibly an additional supply could be mined in any month and be stored cheaply at each source of origin for periodic shipment to each gun.

Agriculturalists will teach the gun personnel, assist in training at village levels and also assist in field demonstrational work.

General Status of Korean Limestone Needs and Major-Reserve Potentials

Province	Programmed (M/T) 1964	1965	1966	Gun (Quarry site)	Reserve mining (Capacity M/T)
Kyonggi-do	31,390	52,300	78,500	Bu-chon	1,052,000
Kangwon-do	6,370	10,600	16,000	Yong-wol Pyong-chang Sam-chok Chang-sun	31,106,606,000
Chungchong-pukdo	11,670	19,500	29,200	Chechon Tan-yang	5,712,844,500
Chungchong-Namdo	32,860	54,800	82,200	Taedok Nonsan Su-san Tangjin	2,648,000
Cholla-pukdo	40,030	66,700	100,100	-	-
Cholla-namdo	84,445	140,700	211,100	Yong-am	18,000
Kyongsang-pukdo	46,315	77,200	115,800	Moon-kyong	30,000,000
Kyongsang-namdo	46,920	78,200	117,300		-
Cheju-do	-	-	-		Marine shells 1/
Total	320,000	500,000	750,000		36,853,169,000

1/ According to a recent survey, two deposits of marine shell found on the northeast and northwest coasts have a high potential for supplying agricultural lime to the island farmers (shipping of limestone from the mainland would make the lime needed too expensive for farm use). However, the shell deposits vary from 32 to 47 per cent CaO and 1 to 4 per cent MgO. Due to heavy-tide action for centuries, these two deposits were formed near Hallim and Songsan-po. The highest per cent CaO deposits would have to be found by chemical means and potentials determined before work would start on supplying liming materials to the farmers. Success must be absolutely ascertained before expensive excavations are started.

c. NACF responsibilities:

Assist the provincial people in carrying on the liming program, including credit facilities, training and guidance of credit personnel needed, etc.

d. ORD responsibilities:

(1) Supplying technical training and published materials.

(2) Supplying soil testing reagents and equipment.

(3) Teaching materials such as flip charts, films,etc.

(4) Doing research to assist in future training.

e. Control laboratory:

Limestone supplies inspected by a Certifying Laboratory at undetermined but frequent intervals. Samples taken at source, in transit or at farmer's field.

Provincial office will control laboratory for determining particle size and neutralizing power of limestone within award specifications and see that limestone is available to farmers in sufficient amounts during total year at each village level to meet each village needs.

f. Other cooperators:

Agricultural schools, colleges, 4-H clubs, etc.

H. Tentative Liming Program Budget.

MAF submitted the following tentative budget for the 1966 liming program.

1. 1966 Limestone program proposal (MAF):

a. It is thought that the price to be paid by the farmers should be maintained at the 1965 level.

Estimated sale price per M/T	₩1,327.00
Governmental subsidy per M/T	597.15
1965-farmer's costs	729.85

Requirement for subsidy - (750,000 M/T program) ₩447,862,500.00

1966 budget proposal	290,925,000.00
Shortage to meet total subsidy	156,937,500.00
1/ Soil acidity testing kits and reagents (3,600 sets)	10,800,000.00
Cost of testing 1,875,000 samples @₩15	28,125,000.00
Total	38,925,000.00
1966 budget proposal	2,128,000.00
Shortage to meet soil testing program	36,797,000.00

Needed warehouses constructed at village level within three years, shared equally by village and ROKG.

Total cost ₩12,000.00 per warehouse - 5,900 warehouses

Each year @₩ 6,000.00 ₩35,400,000.00

Scales to be used at village level:

Scale at each 18,625 villages

@₩ 700 ₩13,036,100.00

1/ Kits with needed reagents should be cheaply prepared and replaceable reagents prepared and bottled at ORD, Suwon, at frequent periods to meet all needs at village level. This is under discussion.

2. Proposed government selling price of lime in 1966:

Subject	Price 1964 ₩	1965 ₩	1966 Est. ₩	Remarks
FOB (prime cost)	273.83	287.14	315.85	10% increase annually.
Transportation & handling cost	544.21	751.30	786.64	CY '66 MAF planted extension of transport to village level.
(Railroad)	(200.39)	(300.83)	(300.83)	Included in transportation and handling cost above.
NACF storage	7.86	13.12	118.08	CY '66 MAF planted extend of storage days up to 75 days from 15 days. (80% increase in storage charge)
Loss	Unknown	Unknown	13.13 est.	One per cent loss from quarry to farm.
NACF handling	33.03	30.90	92.70	Same figures as used for all fertilizer materials.
Total	858.84	1,082.46	1,326.40	

I. Other Supplementary Information and Remarks.

The following data sheets and one map are attached:

1. General status of Korean limestone needs and major reserve potentials.

2. Lime status of limestone mining lots and production by years and months.

3. Status of lime supplied by provinces in 1964 and programmed for CY 1965 and 1966.

4. Map of major limestone deposits with possible shipping centers and connecting railway system.

Data compiled as of Dec. 31,1962
IMD-M, USOM/K

Limestone Deposits in the Republic of Korea

Name of district and/or quarry	Location: Myon	Location: Gun	Location: Province	Reserves in M/T	Production in MT/Yr.	Average chemical composition: CaO	NgO	SiO_2	Fe_2O_3	R_2O_3	Ig. Loss
1. Mukho	Pukpyong-ni	Samchok	Kangwon	54,140,000		-50%	-4%				
2. Hawolsan	Nokok	Samchok	Kangwon	3,022,512,000		50.18	2.32				
3. Sinkiri	Sodal	Samchok	Kangwon	2,192,137,000		50.17	0.78				
4. Machari	Sodal	Samchok	Kangwon	969,928,000		50.31	2.90				
5. Baeksan	Sangjang	Samchok	Kangwnn	160,743,000		47.97	2.16				
6. Tongjom #2	Sangjang	Samchok	Kangwon	312,456,000		50.07	0.93				
7. North Hamtae	Sangjang	Samchok	Kangwon	277,778,000		44.08	1.69				
8. South Hamtae	Sangjang	Samchok	Kangwon	160,924,000		50.29	2.06				
9. Changsung	Sangjang	Samchok	Kangwon	213,402,000		46.16	0.95				
10. Tongjom #1	Sangjang	Samchok	Kangwon	499,587,000		46.99	0.91				
11. Murung	Nam	Chongson	Kangwon	3,025,591,000		*45	-4				
12. Mungok	Nam	Chongson	Kangwon	3,711,712,000		*45	-4				
13. Bangje	Singdong	Chongson	Kangwon	973,642,000		*45	-4				
14. Yomi 1/	Sindong	Chongson	Kangwon	398,256,000		*45	-4				
15. Budong	Puk Pyongchang	Chongson Pyongchang	Kangwon Kangwon	2,082,551,000		*45	-4				
16. Wolrae	"	"	Kangwon	1,631,940,000		*45	-4				
17. Chunchon (Hanjon)	Sachon	Yongwol	Kangwon	9,236,651,000		*45	-4				

Name of district and/or quarry	Location			Reserves in M/T	Production in MT/Yr.	Average chemical composition					
	Myon	Gun	Province			CaO	NgO	SiO_2	Fe_2O_3	R_2O_3	Ig. Loss
18. Sangryong **	Nam	Yongwol	Kangwon	757,365,000		47.5	-2	8	0.56	0.98	37.97
19. Kwangchonni (Yondang)	Nam	Yongwol	Kangwon	363,406,000		46.5	1.61	12	1.5	1.7	-
20. Samdaesan	Youngchun Sanchon	Yongwol Tanyang	N.Chung-chong	2,053,770,000		*45	-4	-	-	-	-
21. Songhak-Kapsan	Songhak Sangchon	Chechon Maepo (Tanyang)	" "	2,789,545,000		*45	-4	1.2	0.6	0.2	-
22. Maepo* (Andong-ni)	Maepo	Tanyang	"	1,845,605,000		*45	4	10	0.7	0.5	41
23. Taega (Kosapyong)	Maepo Chokson	Tanyang	"	45,586,000		47.37	1.56	9.36	0.9	0.94	-
24. Tanyang-Kosoo	"	Tanyang	"	2,107,000		*45	-4	7	-	1.4	-
25. Tanyang	Tanyang	Tanyang	"	30,000		53.65	3.16	0.9	0.7	2.7	41.9
26. Samryoksa	Tanyang	Tanyang	"	17,000		50	2	2.82	-	-	-
27. Taedong	Yongjong	Puchon	Kyonggi	12,000		51.28	3	0.62	-	-	-
28. Songbaek	Songsan	Hwasong	"	40,000		50	3	10.64	-	-	-
29. Tangjin	Tangjin	Tangjin	S.Chungchong	10,000		50	3.2	3.20	-	-	-
30. Taedok 2/	Songchon	Taedok	S.Chungchong	1,608,000		54.8	0.83	0.3	0.2	0.23	43.70
31. Yongdong 2/	Yongsan	Yongdong	N.Chungchong	70,000		50	2	-	-	-	-
32. Oryudong 2/	-	Puchon	Kyonggi	1,000,000		41.40	6.62	13.62	-	1.40	60.90
33. Muan 2/ (Mongtan)	Mongtan	Muan	S.Cholla	18,000		43.48	7.20	5.5	0.86	2.44	38
34. Chechon 2/ (Duhang, Songhang)			N.Chungchong	3,000,000		52.28	0.48	9.59	0.7	1.2	36

Name of district and/or quarry	Location			Reserves in M/T	Production in MT/Yr.	Average chemical composition					
	Myon	Gun	Province			CaO	NgO	SiO_2	Fe_2O_3	R_2O_3	Ig. loss
35. Wolam 3/	Samchok-up	Samchok	Kangwon	35,000,000		48.6	0.8	6.5	2.3	0.93	39.6
36. Munkyong 4/	Sinki-ri	Munkyong	N.Kyong-sang	30,000,000		43	1.8	13	2.2	3.5	34.9
37. Sosan 5/	Kunhung	Sosan	S.Chungchong	300,000		49	1	11	-	-	-
38. Nonsan	Kujagok	Nonsan	S.Chungchong	730,000		52.8	Tr.	3.38	0.72	0.30	-
39. Tanyang ***	Tanyang	Tanyang	N.Chungchong	-		54.96	0.28	0.16	0.05	0.26	43.66

*** Limestone Source - Hankook Plate Glass Co. (Inchon) Exact Location and Reserves Unknown.
** Limestone Source - Sangryong Cement Plant, Yongwol. (Under construction)
* Limestone Source - Cement Plant, Tanyang. (Hyundae (under constr.) and Hanil (under constr.))

1/ Decomposed Limestone Deposit, See SH&G Report, Bellows, 1958, and the Bulletin #2, Geological Survey of Korea, 1958.

2/ Information Source: SH&G "Raw Materials for Cement Plant", Bellows, 1958.
3/ Information Source: SH&G "Cement Plant at Samchok", Bellows, 1958. Present quarry pit for Tongyang Cement Co.
Information Source: All others: The Taebaeksan Geological Invest. Report, 1962.
" " : The Bulletins of Geological Survey of Korea.
4/ Limestone Quarry for Daihan Cement Company, Munkyong.
5/ Limestone Quarry for Changhang Copper Smelter.

Analysis of Lime Sand from Cheju Island (ORD/Suwon)

	CaO %	MgO %	CaO(MgOx1.389) %	Neutralizing power (NP) (CaOx1.8) %	Mosture %	pH Value	NaCl %	Mesh Thru 10 %	Mesh Thru 60 %
1.	47.97	3.46	52.78	95.0	0.35	8.45	1.18	100	20
2.	46.86	3.46	51.67	93.0	0.42	8.60	1.11	-	43
3.	49.62	1.14	51.10	92.0	0.37	8.85	0.86	98	5
4.	41.52	3.09	44.61	80.3	0.32	8.60	1.05	97	8
5.	43.26	4.05	48.89	88.0	0.37	8.32	1.68	100	57
6.	17.33	3.65	22.40	40.3	0.76	8.69	0.60	100	60
7.	43.15	4.26	49.07	88.3	0.42	8.41	2.29	100	60
8.	32.97	3.22	37.44	67.4	0.37	8.70	0.70	100	1

Lime Status of Mining Lots and Mineral Production by Year
(Limestone expressed as 50% CaO or equivalent 89.3% $CaCO_3$)

July 22, 1965

Regist. lots	Operat. lots	Operat. kinds	Year	Production M/T	Production by month, in 1963	M/T	Production by month, in 1964	M/T
92	-	14	1955	-	January	104,114	January	118,096
105	27	20	1956	14,256	February	119,006	February	107,266
137	38	30	1957	14,797	March	120,545	March	153,296
221	54	44	1958	670,715	April	113,947	April	210,701
279	71	54	1959	495,328	May	85,470	May	187,678
335	75	58	1960	636,740	June	66,931	June	193,284
393	86	68	1961	1,264,600	July	109,237	July	127,348
496	126	72	1962	1,259,722	August	134,180	August	236,702
514	94	70	1963	1,362,749	September	144,592	September	120,826
619	132	97	1964	2,219,658	October	116,083	October	193,618
					November	126,211	November	358,918
					December	122,733	December	211,928
					Total	1,363,049		2,219,658

Source: Economic Statistics Yearbook
Published by Bank of Korea in 1965.

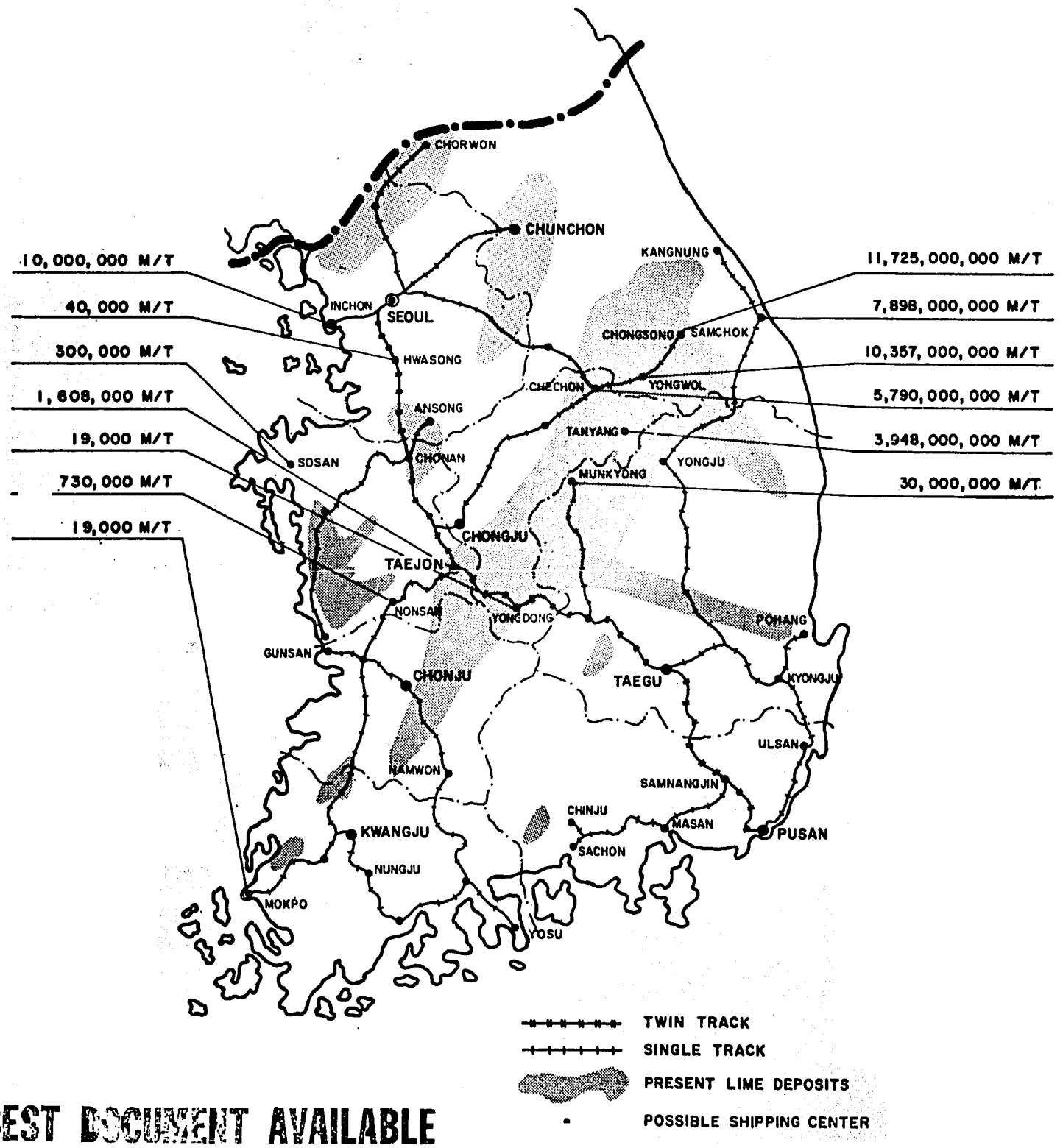
Status of Lime Supplied by Province in 1964 and Programmed for CY 1965 and 1966

	1964 programmed	Actually supplied	%	Won	Programmed CY 1965 (M/T)	Programmed CY 1966 (M/T) 1/
Kyonggi-do	31,390	31,390	100	14,596,350	52,300	78,500
Kangwon-do	6,370	6,370	100	2,962,050	10,600	16,000
Chungchong-pukdo	11,670	11,670	100	5,462,550	19,500	29,200
Chungchong-namdo	32,860	32,833	99.9	15,267,345	54,800	82,200
Cholla-pukdo	40,030	40,030	100	18,613,950	66,700	100,100
Cholla-namdo	84,445	84,150.600	99.6	13,130,029	140,700	211,100
Kyongsang-pukdo	46,315	45,940	99.2	21,362,100	77,200	115,800
Kyongsang-namdo	46,920	46,920	100	21,817,800	78,200	117,300
Cheju-do	-	-	-	-	-	-
Total	300,000	299,303.600	99.76	139,176,174	500,000	750,000

1/ Programmed as recorded in FY 1965 PAAs and agreement in FY 1966 documentation signed by MAF.

Source : Agronomy Yearbook, published by MAF, ROKG , in 1965.

MAJOR KOREAN LIMESTONE DEPOSITS WITH POSSIBLE SHIPPING CENTER AND CONNECTING RAILWAY SYSTEM.



BEST DOCUMENT AVAILABLE

Although many helpful questions undoubtedly could be asked regarding the above tables and map, only a few will be listed below.

1. Can limestone be supplied to all provinces most economically from local deposits?

2. Should there be enforced legislation regarding fineness and neutralizing power limits on the sale of limestone in Korea?

3. Should there be a guarantee on each salable bulk supply? Of what value would the guarantee be to the farmers under Korean conditions?

4. What type of demonstrations and number of demonstrations would suffice? A check (no treatment) should be included in a demonstration with limestone, fertilizer and fertilizer with lime plots or check and a limed plot. Each village should possibly have a demonstration after testing area for pH before treatment. Not logical to have a demonstration on non-acid soil.

5. What kind of training materials (subject matter) are needed? Will flip charts be used?

6. Will provincial people be trained followed by these people training others until village-level leaders are reached? Schedules should make this possible before spring barley planting.