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HOW GREECE CAN PRODUCE MORE FOOD

By CYRIL G. HOPKINS

RESULTS OF LIMESTONE (Λ) AND
PHOSPHORUS (Φ) IN GROWING SWEET CLOVER
(Samples from field trials at Sageika)

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INTRODUCTORY NOTE

The University of Illinois reprints the following document as the last work performed by Dr. Hopkins when on leave of absence from the University which he served for a quarter of a century. It is printed exactly as it was prepared by him, as it was felt that his many friends would be interested not only in the subject matter, but in his method of presentation to the people of Greece.

From the standpoint of science it is believed that special interest attaches to this material from the fact that it is probably the most extensive study that has ever been made by a competent man working on soils that have been farmed so many years as have those of Greece. From the standpoint of permanent agriculture, also, the study is important from the fact that the same methods were used which had characterized Dr. Hopkins' soil experiments in Illinois, and with apparently the same results.

The translation of this work into Greek was the work of Dr. Bouyoucos, a native of Greece, a student of Dr. Hopkins, his constant companion in Greece, and prominently mentioned in the text. Dr. Bouyoucos is now professor in the Michigan Agricultural College.

E. Davenport
Dean and Director

FOREWORD

A wise Christian statesman once said that a nation should keep its promises and preserve its honor, even tho it perish in the effort. He was a practical statesman as well as an idealist; for it was he who first suggested that the American Red Cross Commission to Greece should undertake, along with its program of emergency relief, an agricultural program, with a view to increasing the food production of the country and thus permanently benefiting the entire population.

An Agricultural Department was accordingly made a part of the Commission, and an American scientist who had won world-wide distinction for his practical success in applying to the problem of food production the results of his investigation of the soil, was secured as head of this Department. Major Hopkins has traveled extensively in Greece, has had analyses made of the soils of various regions, and has conducted experiments whose purpose is to enable the farmer to produce larger crops as the reward of his labors.

This report of the Department presents the simple truth regarding the conditions which now exist in Greece, and recommends some practical scientific methods for greatly improving these conditions. It is designed to serve Greece and her people, and this result will be attained if the recommendations are put into practice.

This booklet is presented not only to farmers and landowners, but also to merchants, bankers, teachers, and statesmen; for it is only by the intelligent efforts and influence of all that food production can be largely and permanently increased.

Edward Capps
Lieutenant Colonel, American Red Cross Commission to Greece

ACKNOWLEDGMENTS

To Colonel Edward Capps, Chief of the American Red Cross Commission to Greece, I am very grateful for the honor and privilege of serving as Head of the Agricultural Section to conduct investigations to help Greece to produce more food; also for his constant encouragement and support.

The Government of Greece, including both civil and military authorities and also the railroad and municipal officials, and the many good citizens with whom I came in contact were kind and generously helpful. The continuous passes on the railroads, granted by request of the Government, increased our efficiency; and, at times when we were compelled to change our schedule of travel, these ready passes helped us to avoid some personal hardships. This special mark of interest and confidence in us on the part of the Government will be remembered with very personal appreciation.

The Minister of Agriculture secured upon my request the addresses of more than a hundred thousand farmers and landowners, and by his courtesy this booklet is sent to them free of postage. He has also generously permitted his chemical laboratories to do much work in connection with our agricultural investigations.

Dr. Photios G. Paliatseas, Director of the Agricultural Chemical Laboratory, did much personal work in connection with the daily care of the pot-culture experiments, also in directing and in part performing the chemical analyses of soils and crops; and he has done it all with a generous spirit of interested and intelligent cooperation. I am grateful to him and to his assistants, among whom my special thanks and appreciation are gladly extended to Mr. Perikles Ant. Callergis, Associate Chemist, who performed most of the analytical work, not only with a high degree of skill and accuracy, but with intelligent appreciation of the purposes of the investigations.

Captain George J. Bouyoucos, son of a Greek and a lover of his native land, American by fifteen years of residence and education, a graduate of the University of Illinois, a doctor of philosophy of Cornell University, and a graduate student of European universities, has been for several years a soil investigator for the Michigan Agricultural College. While the Great War was still in full progress, I asked Dr. Bouyoucos if he would come with me to try to help Greece produce more food. He replied at once that he would start any time I wished; and a few days later we were crossing the war zone on our way to Greece. He has been to me a constant and agreeable comrade and a most industrious, intelligent, and sympathetic assistant, interpreter, and translator; he has always been willing to bear his share of the hardships; and he has done it all cheerfully. May Greece and America appreciate the service of this Greek-American.

Cyril G. Hopkins

HOW GREECE CAN PRODUCE MORE FOOD

By CYRIL G. HOPKINS, Ph.D., Major and Deputy Commissioner, American Red Cross Commission to Greece[1]

The average production of the staple food-grains of Greece can easily be doubled with much profit to the farmers, with much benefit to the entire nation, and without the use of more land than is now used for grain production. To bring this about will require three things:

1. That the farmers be convinced that the above statement is true.

2. That they be informed as to the practical methods to be used.

3. That the Greek nation make it possible for the farmers to secure what they need to use for the purpose.

This booklet is issued to influence both public opinion and farm practice, and no apology is made for printing it in the plain and simple language which is understood by all Greeks and spoken by most of them, tho written by few. The best and highest service of language is not to adorn the speaker or writer but to convey thought and knowledge and understanding to the hearer or reader; and, when plain Greek is used to the best advantage by the best writers, it may rival the simple, forceful Anglo-Saxon of the English-speaking people. As St. Paul wrote to the Corinthians: "I had rather speak five words with my understanding, that by my voice I might teach others also, than ten thousand words in an unknown tongue" (*I Corinthians 14:19*).

On the other hand, the farmer must be asked to learn a few plain scientific words which must be used to enable both him and the average statesman to understand the real basis upon which increased food production is possible. Thus, nitrogen, for example, is one of the substances required for the growth of every plant. There is no simpler word for this substance, and it must be assumed that the interested reader, whether a food-producer or only a food-consumer, will use his intellect to learn a few such words, if they are not already known to him.[2]

THE BASIS OF PROSPERITY

Every citizen of Greece should recognize that the primary basis of general prosperity is the soil, from which are produced, directly or indirectly, the principal supplies of food, clothing, and fuel required by most

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[1]Professor of Agronomy, University of Illinois; Chief in Agronomy and Chemistry and Vice-Director, University of Illinois Agricultural Experiment Station. Dr. Hopkins died at Gibraltar on October 6, 1919, while on his way home from Greece.

[2]The above two paragraphs were not included in the Greek publication but are retained here as they stood in the original manuscript.

of the people. The study of the soil, of soil fertility, and of the microscopic life within the soil; and the study of plants, of plant nutrition, and of plant growth, as related to modern agriculture, may afford as much mental development, possess as much cultural value, and furnish knowledge of far greater usefulness, than the study of ancient or foreign languages. Certainly many should study the sciences and principles upon which modern improved agriculture must be based.

Fig. 1.—Results brought about by treating worn-out soils in Macedonia (Near old Pella)

Among the city people it is rather common talk that the soils of Greece are exceedingly fertile, but among the farmers it is common knowledge that the average soil used for wheat and other grains is of low productive power. A thoro investigation reveals the fact that the farmers' knowledge is correct and that the contrary opinion is wrong; but these opposite beliefs tend to balance or neutralize each other, as tho one horse were hitched before and the other behind the plow, pulling in opposite directions; whereas, the banker, for example, should intelligently encourage the farmer to make his soil more fertile.

BETTER SYSTEMS FOR GREATER GREECE

The average yield of wheat in Old Greece is 60 okas per stremma, or about 75 kilograms per stremma, four okas being equal to about five kilograms.[1] Since Greece has already adopted the world system of metric measures for distances (meters, kilometers, etc.), for surfaces (10 stremma make 1 hectar), and for weights as related to drugs and all exports and imports, it seems so nearly certain that in her new expansion the nation will make full use of the metric system that the statistical facts published in this booklet relating to soil fertility and crop production are given in kilograms, not in okas. The difference between these two weights is small in comparison with the difference in prices from time to time. It is not much to learn that 15 kilograms of seed sown per stremma is the same as 12 okas, or that the price of 1 drachma per kilogram is the same as 1.25 drachmai per oka.

When 75 kilograms of wheat are harvested from 15 kilograms of seed per stremma, the return is five of crop from one of seed sown. This is

[1]This is the equivalent of approximately 11.2 bushels per acre. A stremma is equal to .247 acre. A kilogram is equal to 2.2046 lbs.—*Editor's note.*

the general average for Old Greece, the average from more than three million stremmas of wheat seeded and harvested yearly. But in every neighborhood, and on almost every farm, there are some spots of ground where the crop is two or three times as good as the average. No fact is better known to farmers than that soils differ in productive power, even in the same season and with the same kind of plowing and the same kind of seed. On a farm in Thessaly, I harvested the crop from a small area where the growth was very good, and also the crop from another area of the same size where the yield was poor. In the one place the crop yield was eight times as much as in the other, and yet the seed and plowing and the rainfall and sunshine were alike for both places.

The accompanying picture shows a spot in Macedonia on which the yield was very good, while the average of the field was very poor, as can be seen in the same picture. The crops harvested from equal areas are shown in the second picture. On the average land the plants are few and short, while, on the small area of enriched soil, the plants in an equal area are many and tall.

GOD'S COMMANDMENT DISOBEYED

The great agricultural problem of Greece is to enrich the soil. This is a duty which has long been neglected, and even against the commandment of God, for in the first chapter of the Holy Scriptures we read: "And God said unto them, Be fruitful and multiply, and replenish the earth and subdue it" (*Genesis 1:28*).

The first part of this commandment has been obeyed, for the people have multiplied, but the second part has been disobeyed, for they have taken from the soil and have not replenished it. Instead of subduing the earth and having dominion over it and making it produce larger crops, the people of Greece have abandoned vast areas of land once cultivated.

Fig. 2.—Yields from areas of the same extent of rich and poor soil (Near old Pella)

The replenishment or enrichment of the soil is by far the most neglected factor in the agricultural practice of the country. In general, the Greek farmer, with his common plow and hoe, does a good job in the plowing and preparation of his fields. Expensive modern implements would save human labor, but they would not make the soil produce much larger crops, and of course their use is impossible on much of the land now used for food grains.

In general, the farmers use good seed and do a good job of seeding, and they secure a good stand of plants. Of course, some improvement in seed is often possible and most farmers are eager to secure the best seed; but to change the seed or methods of seeding would not greatly increase the food supply of Greece.

No permanent change in climatic conditions has ever occurred anywhere on the earth in all human history. The people talk much of drouth and of bad weather, but the talk is useless, for talk does not change these conditions.

THE NEGLECTED FERTILITY

There is one and only one means by which a large increase can be secured in the yield of crops on the average land now used for growing grain, and that means is by the enrichment of the soil. Man is not responsible for the weather, but he is responsible for the fertility of his soil. He can obey the commandment to replenish the earth. He takes care that his animals have food, and he should take care also that his crops have the food they need.

By intelligent, profitable soil enrichment the average crop can be more than doubled without change of seed or season, and without change of implements or methods of tillage; and this result will be achieved if a fair share of the nation's intelligence and energy is devoted to the effort.

Let us study the following basic facts relating to this problem which is of such vital importance to every citizen, and then let every citizen be ready to act or to exert influence to make more food in Greece.

SIMPLE FARM SCIENCE

Bread is made of wheat, but what is wheat made of? Everyone knows that animals must have food, but the fact is that plants must also have food if they are to grow and yield a harvest. The necessary food of plants consists of ten simple primary substances, known in chemistry as elements. Of these ten elements, five are supplied always in abundance by nature, by God. But "we are laborers together with God," and the other five are left for man to study, and to supply if necessary.

The five elements always naturally well provided are carbon and oxygen (secured by the plant leaves from the air in the compound called carbon dioxid), hydrogen (secured from water absorbed by the roots), and iron and sulfur, both of which are taken from the soil and are naturally and permanently provided in sufficient abundance to meet the needs of large crops.

The five elements left for man's consideration are nitrogen, phosphorus, calcium, potassium, and magnesium. These are secured from the soil by all plants, altho under certain conditions, nitrogen may also be secured from the air by one class of plant, known as legumes, including such as the clovers, lupines, vetches, peas, and beans.

These ten elements are required to make plants grow, just as certainly as food is required to make animals grow.

FERTILITY MAKES WHEAT

Thus, in the famous experiment station of Rothamsted, England, in field trials running sixty years, the general average yield of wheat without soil enrichment was 85 kilograms per stremma, but 249 kilograms per stremma where the five elements nitrogen, phosphorus, calcium, potassium, and magnesium, were applied. During the last ten years, the average yields were 68 kilograms on the common land and 251 kilograms where the soil was enriched.

Likewise, after similar trials with barley had been in progress at the Rothamsted station for half a century, the average yield for a ten-year period was more than four times as great where the soil was enriched as where it was not.

On my own farm in America the yield of wheat in 1917 was 296 kilograms per stremma as the average from 68 stremmas where the soil was made rich, and only 52 kilograms per stremma as the average from six stremmas of land not enriched. Thus, when the soil was enriched the crop harvested was twenty times the seed sown, while without soil enrichment the harvest was about four times the seed.

The average yield of wheat for the entire Kingdom of Denmark for a ten-year period is 273 kilograms per stremma, compared with about 75 kilograms for Old Greece. But in Denmark soil enrichment is intelligently encouraged and practiced.

These results from long trials, from farm experience and from a nation's practice, are cited to prove the importance of soil enrichment. Many other similar results could be cited if necessary.

SOILS DIFFER

Not all soils are deficient in all of the five elements mentioned. Some soils are poor in only one element and rich in all others; but a chain is no stronger than its weakest link, and if the soil is poor in nitrogen, for example, then the wheat crop will be poor, even tho all the other necessary elements are present in abundant supply. Many soils are poor in two elements, and some are poor in three elements, but rarely is a soil found which is poor in more than three elements.

But one soil may be poor in nitrogen while another may be poor only in phosphorus or in calcium. Or one soil may be poor in nitrogen and calcium, while another may contain plenty of those elements but be poor in phosphorus or potassium or, rarely, even in both phosphorus and potassium.

In which elements are the different soils of Greece rich or poor? It was to answer this question that the members of the agricultural section of the American Red Cross devoted almost a year to the personal examination of the soils and crops in the different important and extensive agricultural areas in various parts of the country, extending the investigation from the regions about Sparta and Pylos to those about Lamia, Yanina, Kastoria and Drama; and, of course, to many other important agricultural sections in northern, central, and southern Greece, and in the large island of Crete.

More than three thousand different samples of soil were collected, and these were combined into about eighty composite samples, each representing the trustworthy average of an important soil area.

THE SOILS OF GREECE

In the accompanying table are given brief records of the soil samples collected and also the amounts of the different important elements of fertility found in 200,000 kilograms of the soil. This is the weight of one stremma of soil to a depth of about 15 centimeters, so that these tables give the fertility in the plowed soil per stremma. This is the stratum which may be enriched by adding fertility and plowing it into the soil, and the yield of the crop is governed largely by the fertility in this plowed stratum. (As noted in the tables, a few samples of subsoil were collected and analyzed.)

As collected each soil sample was given a number. For the convenience of the reader of the accompanying table, these numbers are included both on the left-hand page in connection with the record of the samples and on the right-hand page in connection with the fertility content of the soils. The name of the town or village near which the soil was collected is also repeated. It will be noted that these numbers and names of places are grouped. Such grouping indicates that the places are in the same region. Thus the grouping of Nos. 14, 15, and 16 indicates that the small villages of Likochia and Imbraim are near Megalopolis.

The physical character of the soil is usually well known to the farmer. However, to further help him to recognize the soils investigated, these characters are given in the last column on the left pages of the table.

In decreasing order of size, the physical particles of soils are classified as stones, gravel, sand, silt, and clay. Clay is a peculiar substance. When wet it is gummy or sticky, somewhat like dough; and on drying, the mass tends to contract and crack. The particles of clay are extremely small, too small to be recognized physically, except when they are massed together. The other classes of particles are much alike, differing only in size, the silt being finer than sand, and the gravel and stones being coarser. Thus, silt is not at all like clay, but it differs from fine sand only in being still finer.

In addition to these earthy particles, soils usually contain more or less organic matter from partially decomposed plant roots or other vegetation. When moderate amounts of organic matter are present, the soil is called a loam, while a soil containing a large amount is called muck, if much decomposed, or peat, if not much decayed.

Most soils are mixtures of several classes of particles, and the description of the character or type of soil only indicates which are most prominent. For ease of tillage and of root penetration and for the absorption and retention of moisture, the silt loams and sandy loams are usually the best soils; but of course the fertility content and its liberation are, as a rule, the most important factors relating to soil improvement, because soils can easily be enriched in fertility or be so treated as to increase the liberation for plant growth of the fertility which they contain, while no great changes in the physical composition can be made by any practical means. Thus a poor clay soil can be made rich and productive, but it will still be clay and hard to work.

THE MEANING OF SOIL ANALYSIS

In the table are given the total amounts of the different plant food elements contained in the different soils, and these data are worthy of careful study. First of all, it will be seen that soils differ very greatly in fertility, as measured by chemical analysis.

Thus, the nitrogen in the plowed soil per stremma varies from less than 150 kilograms (as in Soil 9 from Sageika) to more than 500 kilograms (as in Soil 33 from Armeni, Crete).[1]

The phosphorus varies from 21 kilograms in Soil 12 near Lappa to more than 200 kilograms in several soils, and even to more than 1,000 kilograms in Soil 43 near Yanina.

The potassium, tho generally very abundant, varies from 252 kilograms in Soil 79 (an abnormal soil near Marathon) and 714 kilograms in Soil 1 near Thebes, to 6,449 kilograms in Soil 65 near Serres.

The magnesium varies from 176 kilograms in Soil 47 near Keletron-Kastoria (with only 44 kilograms in the same weight of subsoil) to 4,615 kilograms in Soil 18 near Thebes; and the calcium varies from only 290 kilograms in Soil 34 near Chania, Crete, to 12,714 in Soil 24 near Kalabryta.

LIMESTONE AND ACIDITY

Limestone always contains much calcium and it usually contains some magnesium, while some limestones (dolomites) contain both calcium and magnesium in large amounts. Usually the soil samples were not analyzed for calcium or magnesium when they were found to contain much limestone. (Of course some such soils are much richer in calcium than Soil 24.)

[1]Soil 79 is not included in this comparison. Being a muck soil, it is of course extremely high in nitrogen.—*Editor's note.*

TABLE 1.—RECORD OF SAMPLES COLLECTED OF SOILS OF GREECE

Commonly each surface sample is a composite of many smaller samples taken to represent the average of an extensive type of soil in the respective region indicated.

Soil No.	Town nearby	Topography of land	Agricultural condition	Character of soil
1	Thebes	Valley slope, nearly level	Grain fields	Sandy clay loam
2	Larissa	Hill land, rolling	Grain fields	Gravelly loam
3	Larissa	Upland valley, nearly level	Grain fields	Clay
4	Lamia	Valley slope, nearly level	Grain fields	Silt loam
5	Lianokladi Junction	Hill land, sloping	Grain fields	Gravelly clay
6	Arbanitsa	Piedmont, gently sloping	Grain fields	Clayey silt
7	Pylos	Valley, nearly level	Grain fields	Limy clay
8S	Gargalianoi	Plateau, nearly level	Abandoned fields	Subsoil, clay
9	Sageika	Coastal plain, undulating	Grain fields	Sandy loam
10S	Sageika	Coastal plain, undulating	Grain fields	Subsoil of 9, clay
11S	Sageika	Coastal plain, undulating	Timberland	Subsoil, clay
12	Lappa	Coastal plain, nearly level	Waste land, brush	Clayey, sandy loam
13S	Lappa	Coastal plain, nearly level	Waste land, brush	Subsoil of 12, sandy clay
14	Likochia	Mountain slope, terraced	Grain fields	Stony clay
15S	Megalopolis	Ridge land, rolling	Waste land, brush	Subsoil, clay
16S	Imbraim	Ridge land, rolling	Waste land, weeds	Subsoil, clay
17	Larissa	Upland valley, nearly level	Grain field	Clay (pot cultures)
18	Thebes	Valley slope, nearly level	Grain field	Sandy clay loam (pot cultures)
19	Sageika	Coastal plain, undulating	Grain field	Sandy loam (pot cultures)
20	Sageika	Coastal plain, nearly level	Grain field	Sandy loam (field experiments)
21	Gargalianoi	Plateau, undulating	Abandoned fields	Silty clay
22S	Gargalianoi	Plateau, undulating	Abandoned fields	Subsoil of 21, clay
23	Gargalianoi	Plateau, nearly level	Abandoned fields	Silty clay (culture experiments)
24	Kalabryta	Mountain slope, terraced	Grain fields	Silty clay
25	Bysoka	Valley delta, nearly level	Grain fields	Gravelly, sandy clay
26	Megalopolis	Hill land, very sloping	In part abandoned	Clayey silt
27	Megalopolis	Ridge land, nearly level	Abandoned, scrub trees	Silt loam
28S	Megalopolis	Ridge land, nearly level	Abandoned, scrub trees	Subsoil of 27, clay
29	Megalopolis	Ridge land, undulating	In part abandoned	Gravelly silt loam
30S	Megalopolis	Ridge land, undulating	Abandoned, scrub trees	Subsoil of 29, clay
31S	Mpilali	Ridge land, rolling	Abandoned, scrub trees	Subsoil, clay

TABLE 1.—FERTILITY IN SOILS OF GREECE

Kilograms per stremma in plowed soil, about 15 centimeters in depth (200,000 kilograms of the dry fine soil). By multiplying by 10, these figures may easily be converted into pounds per acre in 2 million pounds of surface soil (0 to 6⅔ inches). Subsoil numbers are marked "S".

Soil No.	Town nearby	Nitrogen	Phosphorus	Potassium	Magnesium[1]	Calcium[1]	Limestone	Acidity
1	Thebes	310	76	714	....	....	11,740	0
2	Larissa	264	65	2,156	....	....	42,140	0
3	Larissa	179	74	3,480	....	....	4,880	0
4	Lamia	207	106	2,579	....	....	7,620	0
5	Lianokladi Junction	187	73	1,324	....	....	16,040	0
6	Arbanitsa	261	168	4,530	....	....	4,300	0
7	Pylos	319	181	3,483	....	....	20,580	0
8S	Gargalianoi	175	74	2,791	1,417	599	0	93
9	Sageika	142	109	1,676	385	606	0	6
10S	Sageika	149	141	2,447	548	407	0	10
11S	Sageika	102	118	1,836	675	997	0	34
12	Lappa	146	21	1,490	354	529	0	8
13S	Lappa	118	53	1,673	660	849	0	9
14	Likochia	518	245	4,328	1,856	2,206	2,310	0
15S	Megalopolis	178	125	3,091	1,029	786	0	77
16S	Imbraim	175	117	2,362	821	572	0	14
17	Larissa	265	105	3,670	1,562	1,951	220	0
18	Thebes	304	122	1,015	4,615	4,265	8,620	0
19	Sageika	288	46	1,629	562	505	0	7
20	Sageika	227	111	2,227	505	607	0	10
21	Gargalianoi	287	102	2,088	892	1,390	0	17
22S	Gargalianoi	177	84	2,495	1,543	1,206	0	603
23	Gargalianoi	348	145	1,944	680	1,480	0	7
24	Kalabryta	372	205	3,192	1,534	12,714	26,600	0
25	Bysoka	396	141	2,318	743	621	630	0
26	Megalopolis	436	145	4,094	....	....	42,180	0
27	Megalopolis	341	38	1,677	522	598	0	7
28S	Megalopolis	172	102	2,185	701	1,171	0	97
29	Megalopolis	199	132	2,037	616	1,069	0	7
30S	Megalopolis	199	102	2,758	809	293	0	5
31S	Mpilali	232	62	3,882	2,059	739	0	1,355

[1]Soils which contained much limestone were not analyzed for calcium or magnesium.

TABLE 1.—*Continued*

Soil No.	Town nearby	Topography of land	Agricultural condition	Character of soil
32	Armeni, Crete	Valley, nearly level	Grain or fallow	Sandy silt loam
33	Armeni, Crete	Mountain slope, terraced	Grain fields	Limy clay loam
34	Chania, Crete	Valley, gentle slope	Grain or fallow	Sandy clay loam
35S	Chania, Crete	Valley, gentle slope	Grain or fallow	Subsoil of 34, sandy clay
36	Souda, Crete	Mountain top, rolling	Grain fields	Clay
37	Knosos, Crete	Mountain top, rolling	Grain or idle	Limy loam
38	Candia, Crete	Valley, nearly level	Grain or vines	Loam
39	Phinika, Crete	Ridge land, rolling	Grain	Limy loam
40	Korytsa	Low valley, nearly level	Grain or meadow	Clayey silt loam
41	Korytsa	Valley delta, very sloping	Grain or fallow	Sandy clay loam
42	Korytsa	Hills or valley ridges	Grain or fallow	Clayey silt loam
43	Yanina	Mountain top, rolling	Grain or fallow	Cherty clay
44	Soudovitra	Valley, gentle slope	Grain or fallow	Silty clay loam
45	Yanina	Ridge land, undulating	Pasture	Silty loam
46S	Yanina	Ridge land, undulating	Pasture	Subsoil of 45, clay
47	Keletron	Ridge land, undulating	Grain or fallow	Clayey, sandy loam
48S	Keletron	Ridge land, undulating	Grain or fallow	Subsoil of 47, sandy clay
49	Keletron	Valley land, nearly level	Grain fields	Clay, very gummy
50S	Keletron	Valley land, nearly level	Grain fields	Subsoil of 49, clay
51	Kastoria	Mountain slope, terraced	Grain and vines	Clay loam
52	Pella	Ridge land, undulating	Grain or idle	Clay loam
53	Koutsopodi	Hill land, rolling	Grain or fallow	Limy silt loam
54	Argos	Steep piedmont slope	Grain fields	Very stony clay loam
55	Argos	Valley, gentle slope	Grain fields	Stony, sandy loam
56	Tatari	Hills or ridges, rolling	Grain or fallow	Silty clay loam
57	Magoula	Valley, nearly level	Grain or fallow	Clay loam
58	Pharsala	Valley, nearly level	Grain	Silty clay loam
59	Lazarina	Plain, nearly level	Cotton	Silty clay loam
60	Kapudji	Valley, nearly level	Grain or forage	Sandy silt loam
61	Salonica	Hill land, rolling	Grain or fallow	Clayey silt loam
62	Dobitsa	Mountain slope, terraced	Grain or fallow	Stony, silty clay
63	Dobitsa	Hill land, rolling	Grain or fallow	Gravelly, clayey loam
64	Zichna	Ridge land, undulating	Grain or forage	Clayey silt loam
65	Serres	Valley, gentle slope	Grain or forage	Sandy loam
66	Drama	Piedmont slope, gentle	Grain or fallow	Clay loam
67	Dokzat	Ridge land, undulating	Grain or fallow	Clayey, sandy loam
68S	Dokzat	Ridge land, undulating	Grain or fallow	Subsoil of 67, clay
69	Philippi	Plain, nearly level	Abandoned	Sandy silt loam
70	Drama	Plain, nearly level	Abandoned	Clay
71	Boutianoi	Mountain slope	Grain or fallow	Shaly loam
72	Sparta	Hills and ridges	Grain or fallow	Limy loam
73	Kamary	Mountain slope, terraced	Grain or fallow	Silty clay
74	Tripolis	Hill land, rolling	Grain or fallow	Stony loam
75	Tripolis	Valley, nearly level	Grain or forage	Silt loam

TABLE 1.—*Continued*

Soil No.	Town nearby	Nitrogen	Phosphorus	Potassium	Magnesium	Calcium	Limestone	Acidity
32	Armeni, Crete	286	30	2,419	1,193	453	0	5
33	Armeni, Crete	577	489	2,535	....	....	71,320	0
34	Chania, Crete	227	71	1,869	605	290	0	5
35S	Chania, Crete	229	102	3,317	673	290	0	5
36	Souda, Crete	429	184	3,902	1,520	949	430	0
37	Knosos, Crete	313	91	1,315	....	....	148,740	0
38	Candia, Crete	227	111	2,229	....	....	63,080	0
39	Phinika, Crete	343	143	2,547	....	....	86,040	0
40	Korytsa	425	167	4,232	....	....	8,840	0
41	Korytsa	231	124	1,900	736	4,352	190	0
42	Korytsa	232	145	4,720	1,240	2,246	1,180	0
43	Yanina	440	1,172	2,235	....	....	4,280	0
44	Soudovitra	290	352	3,220	1,098	1,600	0	10
45	Yanina	232	183	2,206	645	944	0	53
46S	Yanina	201	143	2,685	1,143	615	0	244
47	Keletron	228	101	3,066	176	418	0	5
48S	Keletron	223	121	3,669	44	333	0	7
49	Keletron	286	61	2,379	947	802	0	10
50S	Keletron	176	105	3,838	1,777	1,575	0	112
51	Kastoria	259	164	4,549	....	....	9,160	0
52	Pella	293	168	4,749	....	....	12,640	0
53	Koutsopodi	257	102	1,716	....	....	115,880	0
54	Argos	439	167	3,990	....	....	3,880	0
55	Argos	228	153	2,668	....	....	9,740	0
56	Tatari	380	104	2,703	....	....	41,100	0
57	Magoula	300	75	3,541	1,751	2,683	480	0
58	Pharsala	416	255	2,681	4,523	4,371	1,260	0
59	Lazarina	318	186	3,738	2,834	1,812	680	0
60	Kapudji	288	155	2,101	4,559	6,302	520	0
61	Salonica	289	103	1,971	....	....	27,480	0
62	Dobitsa	287	102	3,284	....	....	73,040	0
								0
63	Dobitsa	232	104	4,263	....	....	50,900	0
64	Zichna	204	166	5,721	....	....	8,520	0
65	Serres	170	202	6,449	....	....	8,820	0
66	Drama	303	152	3,899	1,529	2,745	1,040	0
67	Dokzat	184	81	3,044	310	506	0	7
68S	Dokzat	146	73	3,339	429	372	0	5
69	Philippi ruins	199	41	3,843	342	1,030	0	5
70	Drama	265	73	2,349	525	1,233	0	7
71	Boutianoi	228	122	4,505	1,556	653	0	7
72	Sparta	285	153	2,173	....	....	56,300	0
73	Kamary	410	188	3,993	1,514	2,361	940	0
74	Tripolis	257	143	3,275	....	....	8,180	0
75	Tripolis	257	112	2,348	3,139	1,460	0	5

TABLE 1.—*Continued*

Soil No.	Town nearby	Topography of land	Agricultural condition	Character of soil
76	Liopesi	Piedmont slope	Grain or fallow	Very stony loam
77	Marathon	Piedmont slope	Grain or idle	Stony loam
78	Marathon	Piedmont slope	Grain or fallow	Sandy loam
79	Marathon	Coastal plain, level	Rice or corn	Limy muck
80S	Marathon	Coastal plain, level	Rice or corn	Subsoil of 79, limy clay
81	Sageika	Coastal plain, level	Grain or pasture	Clay over marl

Limestone is a mild alkali, which is the opposite of an acid. Hot water and cold water cannot exist together, for the one neutralizes the other. Likewise, alkali and acid cannot exist together. Vinegar is acid, and if powdered limestone is added to vinegar the acidity of the vinegar will be destroyed.

Most of the soils of Greece contain plenty of limestone, but this is not the case with all Greek soils, for some of them not only contain no limestone, but they show acidity. Limestone is somewhat soluble in soil water and is contained in most well waters and spring waters of Greece. Sometimes, where there is no natural source of renewal, the limestone is all removed from a soil by the drainage waters, and subsequently the soil may become acid, because acidity is produced in the decomposition of organic matter, as, for example, in making vinegar from sweet cider or from sweet wine, in the souring of milk, etc.

The acidity produced in a soil is likely to collect or accumulate in the subsoil, and, consequently, when the surface soil contains no limestone it is important to test the subsoil for acidity. In the last column of the right-hand pages of the table are given the amounts of acidity found in the acid soils, as measured by the amount of limestone that the acidity would destroy. Thus, to correct or neutralize the acidity in 200,000 kilograms of Soil 31 near Mpilali would require 1,355 kilograms of limestone and that much limestone would be destroyed in the process.

A soil which contains no limestone and no acidity is neutral, while an acid soil is below zero with reference to limestone. Thus, Soil 31 would require 1,355 kilograms of limestone to bring it up to the zero point. If two tons (2,000 kilograms) of limestone were mixed with this soil, it would then contain only 645 kilograms of limestone. If a little powdered limestone is added to a glass of vinegar, the limestone will be destroyed, and at the same time an equivalent amount of acid in the vinegar will be destroyed. After enough limestone has been added to destroy all the acid in the vinegar, then the liquid becomes neutral, and more limestone can then be added without being destroyed.

The limestone in the soils analyzed varies from 148,740 kilograms in Soil 37 near Knosos, Crete, down to 1,355 kilograms below zero (1,355 kilograms less than none), as it might be expressed, in Soil 31.

TABLE 1.—*Continued*

Soil No.	Town nearby	Nitrogen	Phosphorus	Potassium	Magnesium	Calcium	Limestone	Acidity
76	Liopesi	316	205	3,222	....	....	20,160	0
77	Marathon	402	154	3,685	1,755	2,858	520	0
78	Marathon	228	163	2,500	....	....	18,180	0
79[1]	Marathon	654	67	252	....	....	71,950	0
80S	Marathon	348	93	4,022	....	....	60,740	0
81	Sageika	205	52	2,233	1,258	2,032	600	0

[1]No. 79 is a light-weight muck soil and the amounts of fertility reported are found in 100,000 kilograms per stremma about 15 centimeters in depth.

VALUE OF SOIL ANALYSIS

Certainly chemical analyses, properly made and wisely reported, of soil samples intelligently collected, give much information concerning the fertility of soils. This information, used understandingly, is valuable. Why do the farmers cultivate small areas of sticky clay soil, cleared and terraced at large expense, on the steep, rocky mountain slopes, as near Likochia (Soil 14), while vast areas of land of very good topography and of much better texture lie agriculturally abandoned, as on the coastal plain near Lappa (Soil 12) ? The answer is undoubtedly found in the fact that the Likochia soil contains ten times as much phosphorus as the Lappa soil and from three to five times as much of the other important elements of fertility.

Likewise, in all physical respects, the abandoned nearly level ridge land in the Megalopolis valley (Soil 27) is much better for farming than the mountain slope near Kalabryta (Soil 24), and the nitrogen content is nearly equal; but the Kalabryta soil contains five times as much phosphorus, twice as much potassium, three times as much magnesium, and twenty times as much calcium; it is also rich in limestone, while the Megalopolis soil is acid in its surface and more acid in the subsoil, and of course, contains no limestone.

These comparisons are interesting because they plainly indicate that soil analysis may be of much service to agriculture. However, the question remains as to how much of the different elements a good soil should contain. First, we should understand that while the analysis is very helpful, it does not furnish all the information required by one who wishes to improve his soil.

SOILS POOR IN NITROGEN

The highly productive black prairie soil of the great agricultural states of America contains about 700 kilograms of nitrogen per stremma of plowed soil to a depth of 15 centimeters, and where the amount falls below 500 kilograms, methods must be practiced which will provide some additional source of nitrogen if large crop yields are to be secured.

No soil was found in Greece which contained 700 kilograms of nitrogen, and only three soils were sampled which contained more than 500 kilograms. These are Soil 79 (abnormal) and Soils 14 and 33, both found among the limestone rocks and terraces on the mountains. Eleven other soils contain from 350 to 500 kilograms, a fairly good amount, but the other soils examined (four-fifths of the total number) are all either poor or very poor in nitrogen, varying from less than 350 to less than 150 kilograms per stremma of plowed soil.

SOILS RICH AND POOR IN PHOSPHORUS

As a general guide, it may be stated that good productive land of normal physical character contains more than 200 kilograms of phosphorus per stremma of plowed soil to a depth of fifteen centimeters. This statement is based upon the results of soil investigations conducted in different parts of Europe and America.

Of the soils reported in the table, only eight, or one-tenth of the soils examined, contain more than 200 kilograms of phosphorus. All of these are on mountain slopes or low mountain tops or near the foot of mountains. Soils 44, 58, and 65 are all composed of material washed down from the nearby mountain regions. The other quite similar mountain soils contain—184 kilograms in Soil 36 near Souda, Crete, 164 kilograms in Soil 51 near Kastoria, and 188 kilograms in Soil 73 near Kamary-Tripolis. As an average these eleven soils contain 333 kilograms of phosphorus per stremma to a depth of 15 centimeters.

Other soils from piedmont slopes which seem comparable are Soils 6, 54, 66, and 77; and Soil 7 represents a deposit washed from the nearby mountain region. These soils contain between 150 and 200 kilograms of phosphorus. Soils 26, 37, and 62 average nearly half limestone, which seems to account for their low phosphorus content.

In general, soils which have been formed from the recent decomposition of limestone and do not still contain large amounts of limestone in the fine earth, are either rich in phosphorus or moderately well supplied. These soils consist largely of impurities contained in the original limestone. They are found among the limestone rocks or terraces on the mountains, on some piedmont slopes, and in some valley deposits washed from such mountain regions.

Otherwise, the most common soils of Greece vary from poor to very poor in phosphorus. This is true of the great coastal and inland plains of nearly level topography, of the broad inter-mountain valleys and plateaus, and of the low hills and ridges. Most of the idle or agriculturally abandoned lands are very poor in phosphorus, altho a few exceptions were found—eroding hillsides (Soil 26) and low, poorly drained valley land (Soil 40), both with physical difficulties; or where acidity (Soil 45) or greater deficiency of some element other than phosphorus may prevent the frequent production of profitable crops.

SOILS RICH IN POTASSIUM

In the element potassium, the common soils of Greece are very rich, few of them showing less than 2,000 kilograms per stremma, or ten times the standard minimum set for phosphorus. Undoubtedly the standard for the supply of potassium should be higher than for phosphorus, but there is no known reason for having it ten times as high. Even the soils near Thebes (Soil 1) and Knossos (Soil 37) contain about ten times as much potassium as phosphorus, but they are poor in phosphorus.

The only soil found which is very poor in potassium is the muck soil near Marathon (Soil 79). Similar soils in America containing as much as 300 kilograms of potassium per stremma in the surface 15 centimeters have given very large and very profitable increases in crop yields by the addition of potassium. However, in one case in America a subsoil rich in potassium was found under the muck; this was mixed with the muck by very deep plowing and the soil was thus made very productive with no other addition of potassium.

It will be noted that Soil 80 is the subsoil of 79, and that it is very rich in potassium. Adequate drainage and deep plowing to incorporate some of the clay with the muck are recommended for the improvement of this soil. (Phosphorus may also be needed.)

In all Greece, we found no soil for whose improvement we can recommend the purchase of potassium in artificial or chemical fertilizer.

MUCH LIMESTONE AND NONE OR WORSE

For good production, a soil should contain at least one ton (1,000 kilograms) of pulverized limestone per stremma of plowed soil, and the wise farmer who can control the condition will not permit the amount to fall below 500 kilograms, unless the subsoil between 15 and 50 centimeters in depth contains plenty of limestone, which will lessen the bad influence of a too small supply in the plowed soil. Where the soil contains no limestone and where the subsoil contains acidity, the conditions are very bad; and such soils exist in Greece in large aggregate area and in many widely separated regions, as represented, for example, by Soils 9 to 13 from the coastal plain about Sageika and Lappa; by Soils 15, 16, and 27 to 31 from the ridge lands near the center of the great valley of Megalopolis; by Soils 8 and 21 to 23 from the plateau near Gargalianoi; by Soils 34 and 35 from the sloping land in the center of the valley or coastal plain near Chania, Crete; by Soils 45 and 46 from the low, broad ridge near Yanina; by Soils 47 to 50 from the ridge land and coastal plain across the lake from Kastoria; and by Soils 67 to 70 from the great plain near Drama.

In all these regions some soils may be found on the mountains or piedmont slopes which are rich in limestone, as are also the soils recently derived from these, which may now cover the extending slopes of adjoining plains or valleys. But the acid soils are usually found on plains, ridges, hills, or plateaus which have lost their original supply of limestone and which cannot receive additional supplies washed down from higher lying lands.

Thus, to the east and southeast of Megalopolis, the plain and foothills adjoining the mountain slope are rich in limestone, but the long, broad ridges which project far out into the great valley and which are partly separated from the foothills by depressions across the ridges, present a situation in which acid soil might be expected; and the fact is that while those foothills contain abundance of limestone (Soil 26) the soils on the ridges extending farther into the valley are in part devoid of limestone and are agriculturally abandoned (Soils 27 to 31).

FARMERS CAN TEST SOILS

Fortunately, it is very simple and easy and inexpensive for the farmer himself to test his soil for the presence of limestone. If a drop of hydrochloric acid (or any other strong acid) is placed on the soil, the presence of limestone will cause foaming, because the acid will liberate bubbles of gas (carbon dioxid) from the limestone. If no limestone is found in the soil or subsoil to a depth of 30 centimeters, then the subsoil should be tested for acidity. To do this, make a compact ball, larger than a hen's egg, of the subsoil from a depth of about 50 centimeters. Break this ball in two, insert a piece of blue litmus paper, and press the soil together again. After about five minutes open the ball and note the paper. If it has turned from blue to a reddish color, soil acidity is indicated.

Both acid and litmus paper can sometimes be purchased at small cost from the village doctor. If he does not have sensitive blue litmus paper, it can be secured at cost from the Agricultural Chemical Laboratory at Athens.

FERTILITY IN GREEK SOILS

To summarize the information secured in the general soil survey made by the American Red Cross Commission, it may be stated:

1. All of the normal soils examined are well supplied with potassium, and most of them are very rich in that element. The purchase of potassium in artificial fertilizer is not recommended for the practical improvement of any soil found in Greece.

2. Limestone is present in abundance in most of the soils of Greece, and where limestone is present, it always contains plenty of calcium and there is not likely to be any deficiency of magnesium. But some soils have been found which are not only devoid of limestone, but which have even become sour or acid, and this condition should be corrected by the liberal addition of limestone dust or powder, which will always provide sufficient calcium. For the improvement of acid soils very deficient in magnesium (as Soil 47) the limestone applied should be, preferably, dolomite (calcium magnesium carbonate).

3. The soils found on the terraces among the limestone rocks on the mountains and piedmont slopes are normally rich in phosphorus, and this is also true of soils recently washed from such regions, as in some of the small valleys. But otherwise the soils of Greece are generally poor or very poor in phosphorus, and this is the only element which need be purchased in imported or manufactured artificial fertilizer for the improving of the soils and increasing the food production of Greece.

FIG. 3.—LIMESTONE AND PHOSPHORUS ENABLE MELILOTUS TO GROW IN ACID SOILS (Soil taken near Gargalianoi)[1]

4. All of the normal soils examined will be improved by some addition of nitrogen, and most of the soils of Greece are either poor or very poor in nitrogen. But fortunately there is a way in which the farmer can secure abundance of nitrogen without buying it; and some of the work of the American Red Cross reported in the following pages relates to the practical means of getting nitrogen without buying it, by the proper use of suitable legume plants.

Thus, to double the production of food-grains in Greece by enriching the soils in fertility requires the use of only three materials on any soil, of only two on most soils, and of only one on a few soils. These three materials are limestone, phosphorus, and legumes. Their sources and utilization will be discussed in order.

LIMESTONE IN GREECE

There is probably no country in the world which is better supplied with limestone for soil improvement than Greece, but of course this is of advantage to agriculture and to the nation only when use is made of it.

There are two distinctly different kinds of limestone. In pure form one of these is calcium carbonate, $CaCO_3$; and the other is calcium

[1]The Greek letters shown in the illustrations thruout this bulletin are to be interpreted as follows:
0 = No treatment
Α = Limestone
Φ = Phosphorus
Na = Sodium chlorid (common salt)
K = Kalium (potassium)
M = Melilotus plowed under

magnesium carbonate, $CaMg(CO_3)_2$. These formulas furnish much exact information and they are very easily understood. Thus Ca is the symbol for one atom of calcium, with a combining weight of 40. Mg likewise stands for one atom of magnesium weighing 24; C for an atom of carbon weighing 12; and O for an atom of oxygen weighing 16. The subscript figures mean that the preceding symbol or parenthetic group is taken the number of times indicated.

FIG. 4.—RESULTS OF LIMESTONE IN GROWING MELILOTUS IN ACID SOIL (Soil taken near Sageika)

Thus the molecule of calcium carbonate, $CaCO_3$, weighs 100, or 40 plus 12 plus 48 (three times 16), and the molecule of dolomite, $CaMg(CO_3)_2$, weighs 184. But the dolomite molecule has twice as much power to correct acidity as the $CaCO_3$, because the acidity of the soil merely takes the place of the CO_3 group. Thus 92 kilograms of dolomite is as valuable for soil improvement as 100 kilograms of calcium carbonate, the more common limestone; or 100 kilograms of dolomite has the same power to correct acidity as about 109 kilograms of common limestone, which may be referred to as the standard of comparison for relative purity.

This simple chemistry can be and should be taught in the common schools, and it can be and should be well understood by the farming people, who, of course, have at least as much ability to learn as the people who live in cities. Indeed, the shepherd boy who knows the faces, forms, and names of several hundred sheep, often so that he can recognize their children and grandchildren, may be quite as well educated for his profession as is the city boy who knows more of ancient Greek or other languages. Many of the greatest men were country boys: Woodrow Wilson was not born in New York City; nor Lloyd-George in London; nor Venizelos in Athens. If given a fair chance, the farmer is well able to understand the simple science which relates to his own affairs.

In the accompanying table is reported the relative purity of more than forty samples of limestone from different parts of Greece, including the bedrock of the mountain, some limy subsoils, marl, and limestone "sand."

TABLE 2.—SOME SOURCES OF LIMESTONE IN GREECE

Limestone No.	Town nearby	Source of limestone	Character of material	Relative purity, %
1	Thebes	Roadstone	Crushed	99.7
2	Larissa	Roadstone	Crushed	100.6
3	Larissa	Subsoil	Fine earth	41.2
4	Lamia	Quarry	Bedrock	99.3
5	Lianokladi	Subsoil	Fine earth	45.0
6	Nesion	Roadstone	Crushed	95.8
7	Arbanitsa	Building stone	Blocks	96.6
8	Arbanista	Subsoil	Fine earth	59.8
9	Pylos	Mountain side	Bedrock	98.8
10	Gargalianoi	Mountain side	Bedrock	99.0
11	Likochia	Mountain side	Bedrock	98.0
12	Megalopolis	Old ruins	Blocks	97.4
13	Gargalianoi	In city	Impure "sand"	29.6
14	Gargalianoi	Out of city	Building "sand"	97.6
15	Gargalianoi	Out of city	Building "sand"	96.5
16	Gargalianoi	Out of city	Building "sand"	99.3
17	Gargalianoi	Out of city	Building "sand"	97.5
18	Kalabryta	Mountain side	Bedrock	98.5
19	Kalabryta	Building stone	Bedrock	94.2
20	Armeni, Crete	Mountain side	Bedrock	100.2
21	Armeni, Crete	Mountain side	Bedrock	96.5
22	Souda, Crete	Mountain side	Dark stone	98.8
23	Souda, Crete	Mountain side	Light stone	96.5
24	Souda, Crete	Mountain side	Weathered stone	94.7
25	Souda, Crete	Mountain top	Fallen rock	101.1
26	Chania, Crete	Roadstone	Crushed	98.8
27	Candia, Crete	Rocky hilltop	Black rock	107.5
28	Candia, Crete	Rocky hilltop	Black rock	106.1
29	Korytsa	Stone quarry	Stone for lime	82.9
30	Yanina	Stone quarry	Bedrock	99.0
31	Keletron	Mountain side	Bedrock	98.5
32	Argos	Stone quarry	Bedrock	100.1
33	Pharsala	Mountain side	Bedrock	98.3
34	Drama	Mountain side	Bedrock	100.0
35	Philippi	Mountain side	Bedrock	99.9
36	Dokzat	Roadstone	Crushed	98.8
37	Brylia, Sparta	Mountain top	Bedrock	99.5
38	Tripolis	Mountain side	Bedrock	99.6
39	Tripolis	Roadstone	Crushed	99.4
40	Sageika	Subsoil at 1 meter	Marl	59.2
41	Sageika	Subsoil at 1½ m.	Marl	61.7
42	Sageika	Subsoil at 1½ m.	Marl	57.2

By relative purity is meant, for example, that 100 kilograms of the mountain rock sampled near Drama (Limestone 34) contains 100 kilograms of pure calcium carbonate or its equivalent; that 100 kilograms of the marl found at a depth of 1 meter near the railroad station at Sageika (Limestone 40) is worth as much for soil improvement as 59.2 kilograms of calcium carbonate; or that 100 kilograms of the black dolomite (Limestone 27) found on the hill near the sea about 8 kilometers east of Candia, Crete, is as valuable as 107½ kilograms of pure common limestone.

FIG. 5.—DUPLICATE TEST OF THE EFFECT OF LIMESTONE (Λ) IN GROWING MELILOTUS IN ACID SOIL (Soil taken near Gargalianoi)

FARMERS CAN ANALYZE LIMESTONE

It is easily possible, and often desirable, for the farmer to determine for himself the relative value of any limestone material he may think of using for soil improvement: Take two bottles of about the same capacity as drinking glasses. Fill one nearly full with dilute hydrochloric acid (made from half strong acid and half water) and, if necessary, to reduce troublesome foaming, add a few drops of gas-engine cylinder oil. In the second bottle place 22½ grams of the limestone to be tested. Now weigh both bottles, either together or separately, and record the combined weight. Then partly immerse the second bottle in water to keep it cool and gradually pour part of the acid upon the limestone, shaking gently, taking perhaps five minutes to add enough acid. When the addition of more acid produces no more foaming, then blow the gas out of both bottles, wipe dry, and reweigh them.

For every gram loss in weight the relative purity is 10 percent. That is, if the two bottles weigh 937 grams before the reaction, and 927 grams after foaming ceases, the loss is 10 grams from 22½ grams of the limestone, which means that it is 100 percent pure. If the loss is only 4½ grams, then the relative purity is 45 percent, and 100 kilograms would be worth as much as 45 kilograms of pure common limestone.

A balance which will carry a load of 1 kilogram (1,000 grams) and weigh accurately to $\frac{1}{10}$ gram is very satisfactory for this test. (The village doctor or druggist may have such a balance, and the village school teacher ought to have one.)

The loss in weight is due to the escape of the gas carbon dioxid, CO_2, of which the molecular weight must be 44, and of course 22½ grams of pure $CaCO_3$ contain practically 10 grams of CO_2. The same gas is driven out of limestone on burning, leaving from 100 kilograms only 56 of quicklime, CaO, in the kiln:

$$CaCO_3 \text{ equals } CaO \text{ plus } CO_2$$

Burned lime tends to burn the soil and is not so good as the limestone for soil improvement.

SOURCES OF LIMESTONE

Farmers who have soils deficient in limestone should search for some nearby source of naturally pulverized limestone, such as limy subsoil or a deposit of marl or limestone "sand"; and of course the District Agriculturists should assist the farmers in this search.

Thus, on one side of Gargalianoi are great areas of abandoned acid soil, while on the other side (about 1 kilometer from the city) is an immense deposit called "sand" (Limestone 17), which has been used as building sand by the people of Gargalianoi for hundreds or thousands of years; but I found by testing this material that it is not ordinary sand but a limestone sand, averaging 97.5 percent pure, and already in finely pulverized form suitable for immediate use for improving the acid soils nearby. The extent of this deposit is so great that in considering the extension of the railroad from Kyparisia to Gargalianoi the question of transporting this pulverized limestone to other points should also be investigated.

The marl deposit found at Sageika I also recommend for use in the improvement of the extensive areas of acid soil in that region. Possibly in the digging of drainage ditches, which are there needed in some places,

FIG. 6.—LARGE DEPOSITS OF SANDY LIMESTONE NEAR GARGALIANOI

other marl deposits may be found and taken out for soil improvement, thus bringing two benefits from one operation.

In other regions, where naturally pulverized limestone cannot be found (perhaps at Drama, Keletron-Kastoria, Yanina, Chania, Crete, etc.) water power should be developed, if practicable, to operate limestone crushers and grinders. It is not necessary that they be operated every month in the year. Pulverized limestone may be kept indefinitely, for it does not depreciate appreciably on exposure.

On many acid soils very great improvement can be made merely by the use of limestone and legumes, but of course phosphorus may also be necessary for the best results.

SOURCES OF PHOSPHORUS

The phosphorus supply of the world is found chiefly in deposits of a natural rock called calcium phosphate, $Ca_3(PO_4)_2$. The atom of phosphorus, represented by P, weighs 31, and, from this fact and those previously given, anyone can compute that this molecule weighs 310 and that phosphate rock, if pure, contains 20 percent of phosphorus. In general, the phosphate rock found contains only about 70 percent of this calcium phosphate, corresponding to 14 percent of phosphorus, or 14 kilograms of phosphorus in 100 of the natural rock.

The principal known deposits of phosphate rock are in the United States of America and in northern Africa, from where it must be brought

FIG. 7.—RESULTS OF LIMESTONE AND PHOSPHORUS IN GROWING MELILOTUS (Samples from field tests at Sageika, harvested May 21, 1919)

FIG. 8.—RESULTS OF LIMESTONE AND PHOSPHORUS IN GROWING MELILOTUS (Samples from field tests at Gargalianoi, harvested May 21, 1919)

to Greece. The phosphate rock is sometimes ground to a very fine powder and then applied to the land in connection with fresh organic matter, such as legume crops plowed under with it; but more commonly one ton of the ground phosphate rock is mixed with about one ton of sulfuric acid, making two tons of what is called in Europe superphosphate, but more properly acid phosphate, as it is called in America, for it is an acid product and it contains not a higher percentage of phosphorus than the natural rock, but only about half as much. However, the phosphorus in the acid phosphate is soluble and thus more valuable than in the insoluble natural rock, which, if used, must be made soluble by the decomposition products of the decaying organic matter. It is safer to use the acid phosphate until a good supply of organic matter can be plowed under; then the relative cost will help to decide which to use.

Per hundred, the natural rock phosphate contains about 14 of phosphorus, and the acid phosphate about 7. Sometimes the analysis is reported in terms of so-called "phosphoric acid," by which is meant not true phosphoric acid, but phosphoric oxid, P_2O_5. As one can easily compute from the atomic weights, 14 percent of phosphorus, P, is the same as 32 percent of P_2O_5; and 7 percent of the actual element phosphorus is all that is valuable in acid phosphate guaranteed to contain 16 percent of "phosphoric acid."

Where phosphorus is needed, the initial application may well be 100 kilograms of acid phosphate per stremma, to be spread over the land as uniformly as the seed and then plowed into the soil with the seed of wheat, barley, rye, or oats. Subsequent applications may be from 30 to 50 kilograms per stremma for each grain crop.

For the general prosperity of all the people of Greece, there is no one thing more important than that the farmers should be able to secure an adequate supply of phosphorus at a reasonable cost; and there is nothing else more important for the national government to control than the importation, manufacture, distribution, and sale of phosphate for soil improvement.

If the soils which are deficient in limestone can be well limed, and if those soils which need phosphorus can also be well treated with phosphate, then the one remaining problem of soil fertility relates to the use of legumes; and this concerns practically all of the soils of Greece, including even the mountain soils.

NITROGEN MAY COST MUCH OR NOTHING

Of all the elements essential to plant growth, nitrogen is the most abundant in the supply within reach of the farmer and it is also the most expensive when purchased in artificial fertilizers. The world's great supply of nitrogen is in the air. There is enough nitrogen in the air resting upon each stremma of land to meet the needs of large crops for half a million of years; and science has discovered that there is a way in which the farmers can secure nitrogen from this inexhaustible supply. This way is by means of microscopic organisms, called bacteria, which, under favorable conditions, have power to live in nodules on the roots of one class of plants, called legumes, including the clovers, lupines, vetches, peas, and beans.

Neither the grain crops nor the grasses, nor any other agricultural plants, except legumes, are able to secure nitrogen from the air; and the legumes secure it only by means of the bacteria. Thus it is necessary to have the proper bacteria, and the legume crops must be grown and returned to the soil either by plowing them under or by feeding the crops to animals and returning the manure to the land, as for example, by pasturing.

HOW MUCH NITROGEN IS NEEDED

If the farmer will provide limestone or phosphorus, if needed, as advised in the preceding pages, then he need use only as much knowledge in providing nitrogen for his crops as he would in providing food for his animals or for his family. If he wishes to grow 3,000 kilograms of wheat on 1 hectar (10 stremma) of land, he should know that the wheat will require 100 kilograms of nitrogen, or 10 kilograms for each stremma.

Of course 300 kilograms of wheat per stremma is a large yield, but no larger than can be grown in favorable seasons if the fertility is provided in sufficient amount. How is one to provide 100 kilograms of nitrogen for 1 hectar? One ton (1,000 kilograms) of average farm manure contains 5 kilograms of nitrogen. Thus 2 tons of manure per stremma, or 20 tons per hectar, would provide the nitrogen required for the wheat. If the supply of manure were sufficient, the problem would be solved; but every farmer knows that the supply of manure is not sufficient.

HOW TO GET NITROGEN

The legume crops commonly grown in Greece add very little nitrogen to the soil. Some of them are pulled out, both the tops and roots being removed, and this practice leaves the land poorer in nitrogen. Even when the roots are left in the soil, they will contain no more nitrogen than was taken by the legume crop from a soil of average productivity, so that that practice would not enrich the soil in nitrogen.

To grow a legume crop and turn it all back into the soil is not very satisfactory, because for that year there is some expense and no reward from the land. A better practice, and one which should fit well into the common system of grain and fallow, is to grow a legume crop of large pasture value during the fallow year. For this purpose a clover known by the name of melilotus is worthy of very thoro and long-continued trials. This crop is very hardy, has much ability to resist drouth, and it will also endure much wet weather.

Melilotus has high value for pasture or for hay. It is much used in America and is especially valuable for pasture for all kinds of live stock—cattle, horses, sheep, swine, etc. It is a two-year plant. It may be seeded during the spring, summer, or autumn, the best time depending upon the climatic conditions. The first season it usually makes good growth and develops an extensive, rather fleshy root system. The following spring it makes very rapid growth and may be pastured far into the summer, or harvested for hay before the plants become too rank, or allowed to mature seed. It may also be pastured for a time and then allowed to grow for hay or seed; or, if the crop is harvested early and cut high above the ground, it may then make a later growth for seed or for pasture. To secure a second growth, the plant should be cut early enough and high enough to leave two or more good growing branches on the stubble of each plant.

NITROGEN IN MELILOTUS

One ton of dry melilotus hay contains about 23 kilograms of nitrogen, and the roots contain more nitrogen than the roots of peas, beans, vetches, etc. If the growth of melilotus were equivalent to 600 kilograms per stremma of dry hay, and if 500 kilograms were eaten by pasturing animals, the total nitrogen added to the soil would be more than 10 kilograms per stremma; for, as an average, the excrements from growing or milking animals contain three-fourths of the nitrogen of the feed consumed. Thus the melilotus may furnish much valuable feed for the pasturing animals, and it may also serve as a substitute for 20 tons of manure per hectar. I know of no other legume plant of so high feeding value which will make so good growth and provide so much soil enrichment and which may fit so perfectly into the common system of grain and fallow.

Wherever the soil contains limestone, the melilotus should grow successfully from September or October till June or July; but where the soil is poor in phosphorus, both the melilotus and the alternating grain crops will be benefited by phosphorus fertilizing. In America melilotus is often seeded among the growing grain in midwinter. It lives thru the summer drouth after the grain is harvested, makes a good growth during the autumn, and a large growth the next spring. Whether it will live thru the more severe drouth of the Greek summer is not known, but it is more drouth-resistant than alfalfa or other common clovers.

SOIL ACIDITY AND PLANT DISEASE

On acid soil melilotus will not succeed, nor will alfalfa or any other common clover of a life period of more than one year. Some annual legumes can be grown with a fair degree of success on some soils which do not contain limestone. Among these are the lupine, cowpea, crimson clover, and Japan clover. These are all known in America and all except the lupine are much grown. The lupine has no value for pasture or for hay, and even the seeds must be treated to make them fit for feed. However, where no better plant can be grown, the lupine should have large use for soil improvement and if practicable all of the plant except the seed should be returned to the land.

Most legumes are subject to disease if grown frequently on the same land, and this may account for the increasing difficulty of growing lupines in some parts of Greece, the soil having become "sick" of lupines. So far as known, soils do not become "sick" or diseased from the frequent growing of alfalfa or melilotus.

THE PROOF OF SOIL IMPROVEMENT

In the accompanying table are recorded the weights of green melilotus harvested from thirty-eight pots filled with soil from different parts of Greece and treated as indicated. Since the purpose of these culture experiments was to secure information as easily as possible, the applications made to these pots (and also in the field experiments reported) were more liberal than is recommended for ordinary farming. The pots were nearly 20 centimeters in diameter, with a surface area of about 300 square centimeters. The applications indicated were, per pot, 6 grams of acid

TABLE 3.—MELILOTUS IN POT CULTURES
(Grams per pot of green plants)

Pot No.	Soil treatment[1]	Series A	Series B	Series A	Series B	Averages	
		Soil 17 from Larissa		Soil 18 from Thebes		Four pots	Eight pots
2	0	37.7	40.9	30.4	17.6	32	..
3	P	95.0	108.5	103.7	112.3	105	..
4	PNa	84.2	84.1	125.0	132.5	106	..
5	PK	82.0	74.0	115.8	117.8	97	..
		Soil 19 from Sageika		Soil 23 from Gargalianoi			
2	0	19.0	25.1	9.7	3.9	14	..
3	L	63.0	39.0	23.5	22.2	37	34
4	LP	75.8	67.2	71.0	62.1	69	87
5	LPNa	84.0	88.9	74.3	82.5	82	94
6	LPK	85.0	89.9	72.0	79.8	82	90
7	PK	....	....	30.0	27.6	29	..

[1]0 = No treatment
P = Phosphorus in the form of acid phosphate
Na = Sodium in the form of sodium chlorid (common salt)
K = Potassium in the form of potassium chlorid
L = Limestone

phosphate, 2.975 grams of sodium chlorid, 3.73 grams of potassium chlorid, and 150 grams of limestone.

Phosphorus produced a marked increase in yield in every case, the general average of all trials being 53 grams (from 34 to 87). The soils from Larissa and Thebes both contain limestone, but, where limestone was applied to the acid soils from Sageika and Gargalianoi, it gave a large increase in every case, whether applied alone or in addition to phosphorus and potassium, the general average increase from six trials being 31 grams (from 14 to 52). Thus the results of the pot-culture experiments agree well with those of soil analysis.

POTASSIUM IN DEAD SOILS

Soils may become so poor in decaying organic matter that they are very inactive—almost dead soils, so to speak. Such soils, even tho rich in potassium, may show some increase in crop yield from its application in soluble form. Because of this fact, the molecular equivalent of common salt was also applied, and it produced rather better effects than the potassium salt. The Larissa soil is very rich in potassium, and evidently furnished all the plants could well tolerate, for the addition of either potassium or sodium produced a decrease in yield. On all other soils those salts produced some increase, which was most consistent on the soils from Thebes and Sageika, which contain less potassium than the Gargalianoi soil. With fresh organic matter turned under, as in manure or legumes, the liberation of potassium from the soil is likely to be ample, and these results certainly indicate that, if needed temporarily, the common salt should be used rather than the expensive potassium salt. As the average of trials with barley and wheat grown for sixty years on the fields of the Rothamsted Experiment Station, sodium produced 8 kilograms more barley and 12 kilograms less wheat, per stremma, than potassium.

GOOD GRAIN AFTER GOOD MELILOTUS

After being harvested and weighed, the melilotus from Series A was dried for hay and then analyzed for nitrogen, while that from Series B was partially dried and then mixed with the roots in the soil. The pots of Series B, including some which had not been planted to melilotus, were then planted to millet, in order to show that good grain crops can be grown after melilotus without the use of any other source of manure or nitrogen.

FIG. 9.—PHOSPHORUS (Φ) ENABLES MELILOTUS TO GROW IN SOME SOILS RICH IN LIMESTONE (Soil taken near Thebes)

FIG. 10.—CEREALS GROW BEST WHERE A GOOD STAND OF MELILOTUS (M) HAS BEEN GROWING (Soil taken near Thebes. See Table 4 for yields)

The accompanying tables give the results in detail. Of course, if the melilotus were pastured (not too closely) the profits would be greater, and the yield of grain following might also be greater than we secured, because the melilotus turned into the soil decayed too rapidly, and in the Gargalianoi pots this injured the millet to some extent. (Pot 3 did not recover from this injury.)

TABLE 4.—MILLET IN POT CULTURES (SERIES B)
(Grams per pot of green plant)

Pot No.	Soil treatment[1]	Soil from Larissa	Soil from Thebes	Averages: Two series	Averages: Four series
1	0. . . . .(0)	57	21	39	
2	M. . . . .(M)	56	37	47	
3	MP. . . . .(MΦ)	207	167	187	
4	MPNa. . . . .(MΦNa)	240	215	228	
5	MPK. . . . . .(MΦK)	184	194	189	
		Soil from Sageika	Soil from Gargalianoi		
1	0. . . . .(0)	23	16	20	30
2	M. . . . .(M)	47	14*	30	...
3	ML. . . . .(MΛ)	103	5*	54	50
4	MLP. . . . . . .(MΛΦ)	148	125*	137	162
5	MLPNa. . . .(MΛΦNa)	200	153*	177	202
6	MLPK. . . . .(MΛΦK)	201	116*	159	174
7	MPK. . . . . .(MΦK)		99*		
8	LP. . . . .(ΛΦ)		83		
9	LPNa. . . . . .(ΛΦNa)		80		
10	LPK. . . . . . .(ΛΦK)		82		

[1]M = Melilotus plowed under. For the meaning of other symbols used, see the footnote of Table 3.

The limestone, phosphorus, sodium, and potassium for Pots 1 to 6 were applied before the melilotus was seeded.

*Damaged by ammonia from melilotus which did not change quickly to nitrate in clay soil.

In studying the yields of millet, we must remember that melilotus is a substitute for animal manure, and that the average increase of 112 grams (from 50 to 162) where phosphorus was applied was due in part to the

FIG. 11.—THE EFFECT OF MELILOTUS (M) ON THE SUCCEEDING CEREAL CROP (Soil taken near Gargalianoi)

FIG. 12.—CEREALS GROW BEST WHERE A GOOD STAND OF MELILOTUS (M) HAS BEEN GROWING (Soil taken near Sageika. See Table 4 for yields)

fact that those pots had received, as an average, 87 grams of melilotus as a manure, whereas the pots on which no phosphorus had been applied had received an average of only 34 grams.

In spite of the damage to the Gargalianoi pots, the yield of millet on the best pot (153 grams) was nearly double that on the corresponding undamaged pot (No. 9) which had not grown melilotus. The uniformity of Pots 8, 9, and 10 indicates a uniform lack of nitrogen.

As the general average of results from the four series, the yield of millet was increased from 30 grams to 202 grams by soil enrichment, and without the purchase of either nitrogen or potassium, whose inexhaustible supplies are in the air and soil.

TABLE 5.—HAY AND NITROGEN FROM MELILOTUS (POT CULTURES, SERIES A)
Kilograms per stremma

Pot No.	Soil treatment	Hay	Nitrogen	Hay	Nitrogen
		Larissa soil		Thebes soil	
2	0	340	8	270	6
3	P	710	19	800	20
4	PNa	640	18	970	21
5	PK	630	18	840	22
		Sageika soil		Gargalianoi soil	
2	0	160	4	70	2
3	L	490	13	180	4
4	LP	570	16	580	15
5	LPNa	640	17	590	15
6	LPK	610	17	560	14
7	PK	...	..	260	6

In the accompanying table are given the yields and the nitrogen content of the melilotus hay harvested from Series A of the pot cultures. It will be seen that in all cases where limestone and phosphorus were well provided, the nitrogen contained in the melilotus was more than 10 kilograms per stremma. In fact, the general average was more than 17 kilograms; and, besides that, the roots of the melilotus probably contained half as much as the tops, altho the nitrogen in the roots may be no more than good soil would furnish to any crop. Thus the amounts of nitrogen shown in the table may safely be considered as new nitrogen secured from the air and at no cost if the melilotus for pasture is worth the cost of seeding.

Before the war 17 kilograms of nitrogen cost 34 drachmas in 85 kilograms of ammonium sulfate and much more in mixed commercial fertilizers, and at present this much nitrogen, if purchased, would cost more than 100 drachmas per stremma. For grain and forage crops the wise farmer will take his nitrogen from the free and inexhaustible supply of the air and be independent of the market price.

FIELD TRIALS WITH MELILOTUS

In the pot cultures the plants were watered when necessary, and hence the yields computed per stremma are larger than would be secured during the same time under normal field conditions, but field experiments were also started on similar soils at Larissa, Sageika, and Gargalianoi. Melilotus

FIG. 13.—MELILOTUS IN FIELD TRIALS NEAR GARGALIANOI. ON THE LEFT, NO TREATMENT; ON THE RIGHT, LIMESTONE AND PHOSPHORUS

seeded January 2, 1919, at Larissa was a failure. (Wheat seeded the same day by a farmer on adjoining land was also a complete failure, owing to too much rain for level land.)

At Sageika the land was prepared and seeded the 10th of January and the melilotus harvested the 21st of May, and at Gargalianoi abandoned land was prepared and seeded the 15th of January and the melilotus harvested the 23d of May, 1919. The yields of dried melilotus hay and its nitrogen content computed per stremma are given in Table 6.

In essentials, these field results tell the same story as the pot experiments and agree well with the information secured by soil analysis. The

TABLE 6.—MELILOTUS IN FIELD TRIALS
Hay and nitrogen, kilograms per stremma

Plot No.	Soil treatment	Sageika field		Gargalianoi field	
		Hay	Nitrogen	Hay	Nitrogen
101	O...........	15	.5	22	.6
102	L...........	74	2.2	85	2.0
103	LP..........	309	8.6	315	9.5
Border	P...........	31[1]	1.0[1]	51	1.4

[1]Computed from a later harvest.

use of limestone is very important for improving these acid soils, but both limestone and phosphorus are necessary for the best results with legumes; and of course the legumes are also necessary to secure the nitrogen required by the grain crops to follow.

In these field trials on very poor land on which limestone and phosphorus were applied, the melilotus seeded in January yielded in May per stremma more than 300 kilograms of dried hay and about 9 kilograms of nitrogen, enough for a crop of 270 kilograms of wheat per stremma, which is more than three times the present average yield of wheat in Greece.

These facts must speak for themselves. Greece can easily double her production of food grains if the facts established about the use of limestone,

FIG. 14—MELILOTUS IN FIELD TRIALS NEAR SAGEIKA. ON THE LEFT, NO TREATMENT; ON THE RIGHT, LIMESTONE

FIG. 15.—MELILOTUS IN FIELD TRIALS NEAR SAGEIKA, ON WHICH APPLICATIONS OF LIMESTONE AND PHOSPHORUS HAVE BEEN MADE (Compare with Fig. 14)

phosphorus, and legumes are put into practice on the farms with as much intelligence as is commonly used by Greek farmers in dealing with their other farm affairs.

WINE, TOBACCO, OR BREAD

To the Greeks or foreigners who have advised that I should encourage the production of more grapes and tobacco because they yield more profit per stremma than food grains and forage, I would only say that profit per man is more important than profit per stremma, especially when vast areas of land lie unused or abandoned; that the Government has already reduced the area in vineyards and restricted the exportation of tobacco because of overproduction or unprofitable markets for currants and tobacco; and that raising tobacco or wine for the big buyers or for home consumption is too much like gambling or of too uncertain advantage to the ultimate welfare of the people, to justfy special encouragement by such a public or philanthropic organization as the Red Cross.

I may add that America reduced her annual exportation of wheat (by five-year averages) from 215 million kilos in 1900 to 103 million kilos in 1910 in order to feed her increase of 16 million people; that America furnished wheat to the Allies during the war to preserve civilization only because Americans were willing to eat corn for a time; and that, if the Greeks wish to eat wheat bread in the future, they should prepare to raise the wheat.

RECOMMENDATIONS

As the Red Cross representative of American agricultural investigation and education, I respectfully offer the following recommendations, which are based not only upon my year's study of the present conditions in Greece, but also upon the experience and progress of America in the application of agencies of civilization which ancient Greece did much to originate but in whose modern development Greece has not been permitted to fully share because of foreign domination.

1. That Greece establish as early as practicable a strong college of agriculture and an agricultural experiment station as a worthy and desirable part of the great national University at Athens. The teachers and investigators in this college and experiment station should know well the art of agriculture and understand the difficulties met in farm practice, and in addition they should be as well educated in science, and in its application to agricultural improvement, as are the teachers of law or medicine in their fields. Such a coordinate institution should be and no doubt will be welcomed, respected, encouraged, and helped by the other colleges of the University already great; and such an addition should increase the support and the general appreciation of all departments of the University. An old oriental philosophy says: "Public prosperity is like a tree; agriculture is its roots; industry and commerce are its branches and leaves. If the root suffers, the leaves fall, the branches decay, and the tree dies." Separate schools for agriculture are wholly unnecessary and usually unsatisfactory and unsuccessful, for they tend to share the disrespect which some imperfectly educated people feel and express for the profession of farming, and the best students will not willingly attend separate agricultural schools not generally accorded high educational rank.

The problems of providing food and clothing for all the people of Greece is not less important than healing the sick or settling legal difficulties; but strong students will not enter a college of agriculture unless its position is as respectable and reputable educationally as that of other colleges. Investigations relating to the scientific improvement of agricultural practice belong logically to the University, while regulatory questions belong very properly to the State Department of Agriculture.

2. That courses in agricultural science be offered by the high schools of Greece to be taught as soon as possible by agricultural graduates of the University, and that all high-school students be permitted and encouraged to take some courses in agricultural science or the application of science to agriculture.

3. That the University thru its agricultural experiment station, begin soon a detailed survey of the soils of Greece, making maps to show the extent and boundary lines of the various soil types and determining the general character and average fertility content of each type; and also establish and conduct experiment fields in different parts of Greece on soils representing

the most important and extensive types of agricultural land, especially for the purpose of discovering and demonstrating the most profitable and permanent methods of increasing crop yields.

In these experiments, it is far more important to investigate the value of phosphorus both in acid phosphate and in like cost of finely ground natural rock, in connection with legume crops turned under (directly or after pasturing) and, where necessary, in connection with Greek limestone, than to experiment with potassium from Germany or France or with nitrogen from Chile or from chemical factories. It is also far better to have a small number of well-planned and carefully conducted plots on each of many experiment fields, well distributed over Greece, than to have many plots with impracticable experiments in only a few places.

The following scheme may serve to some extent in planning soil experiments:

PLOT	SOIL TREATMENT
101	None
102	Legumes
103	Legumes, acid phosphate
104	None
105	Legumes, limestone
106	Legumes, acid phosphate, limestone
107	None
108	Legumes, acid phosphate, limestone, sodium
109	Legumes, rock phosphate, limestone, sodium
110	None

Where the plowed soil contains more than one percent of limestone (2 tons per stremma), the limestone application may be wholly omitted, and on Plots 5 and 6 potassium may then be substituted.

With this and a second series of plots to be numbered from 201 to 210 and treated similarly, the common system of grain and fallow could be practiced, legumes being grown in place of fallow where indicated. With a four-year system, such as wheat, fallow, barley, and fallow (legumes where indicated), four such series of plots would permit all crops to appear every year and in rotation.

When needed the initial application of limestone may be one ton per stremma, with subsequent applications of 500 kilograms every four years.

The applications of the phosphate may well be, per stremma, 100 kilograms of acid phosphate or (on Plot 9) 200 kilograms of fine-ground, natural rock phosphate, if the cost justifies it, the applications to be repeated every four years.

The sodium may be applied in 50 kilograms per stremma of common salt (sodium chlorid) and the potassium, if used, in equal cost of potassium chlorid, these applications to be repeated every four years and worked into the soil in connection with the phosphate.

If the rotation covers more or less than four years, the applications should be made once for the rotation but in proportionate quantities.

Each plot may well be ten meters wide and 100 meters long if sufficient uniform land is available, but plots as small as two meters wide and five meters long may give valuable results if the land is well selected and the experiments conducted with care and accuracy. In all plot experiments under normal conditions it is well to have division strips two meters wide between the plots and wider strips between the series, because plant roots will extend more than one meter beyond the plot lines and applied fertility will be moved somewhat in tillage operations.

4. That the Government provide or assure an adequate supply at reasonable cost to farmers of acid phosphate and finely ground natural phosphate (at least 90 percent to pass thru a sieve with 2,000 holes per square centimeter), and assist in the introduction of suitable legumes and in the development of sources of pulverized limestone for use where needed.