SOME PHYSICAL AND CHEMICAL PROPERTIES OF SOILS IN THE BEKA'A PLAIN

by

Andre John Salib

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Approved:

A. H. Sayegh
In Charge of Major Work

[signature]

A. Abdul Karim

H. D. Fuehring

W. W. Worzella
Chairman, Graduate Committee

American University of Beirut

1961

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ABSTRACT

Soils of seven different categories were selected from different locations in the central Beka'a plain according to the soil map by Geze (23). They are:

a. Red soils or terra rosa

b. Recent alluvial soils

c. Greyish white rendzina soils

d. Light chestnut soils

e. Dark chestnut soils

f. Grey soils)
) classified together by Geze
g. Black soils)

Some chemical and physical analyses were run on these soils with the objectives of determining some of the physical and chemical properties of soils of the central Beka'a and their relationship to soil classification. The relationship between available nutrients in the soil, as determined by soil tests, and soil classification was also determined.

In general, all soils were fine in texture with a somewhat high bulk density. The soils were alkaline in reaction and calcareous. Generally, the soils were fairly low in total nitrogen, low to medium in organic matter and quite variable in available phosphorus. The cation exchange capacity ranged high for almost all soils. Exchangeable potassium, available for crop growth, was found considerably adequate in most soils.

Statistical significance at the 5 percent level was observed between some of the soil categories for most of the soil properties determined. No statistically significant differences were observed between the surface and subsoils with regard to the physical and chemical properties studied.

Results of this study indicated that Geze's classification of Beka'a soils was justifiable in that the soils from the various mapping units were found to differ to a considerable extent in certain soil properties.

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INTRODUCTION

Lebanon is a small country on the eastern coast of the Mediterranean, bounded by the Syrian region of the United Arab Republic on the north and east and Palestine on the south.

Two chains of mountains, the Lebanon and the Anti-Lebanon, running from north to south, are separated by the fertile Beka'a plain. Two rivers flow in the plain, the Litani toward the south, and the Orantes toward the north.

The interior plain of the Beka'a, 10 to 15 kms. wide, is about 120-125 kms. in length with altitudes ranging from 600-1100 m. Schematically, it is possible to distinguish southern Beka'a from central and northern Beka'a by the hilly topography occuring in the former. The northern Beka'a, on the otherhand, is distinguished from its central counterpart, by its being the river basin of the Orantes, while central Beka'a is the basin of the Litani (23).

In general, the climate of the Beka'a is cold in winter, dry and hot in summer. The annual average temperature is 15-17°C. Occuring mainly during the winter months, precipitation in the Beka'a varies from region to region. The southern part receives between 900-1000 mm. of rainfall where the mountains do not form a barrier for rain incoming from the sea. A marked decrease in rainfall occurs northward. The central Beka'a receives between 400-700 mm. The northern Beka'a gets between 200-400 mm. of rainfall. The relative humidity in the central Beka'a varies considerably between winter and summer.

It averages about 75 percent in winter, and 45 percent in summer as reported by Ksara weather station (23).

The major part of the Beka'a is under dry land farming. The main crops are wheat, barley, lentils, vetches, chickpeas, watermelon, baki and grapes. The irrigated crops are onions, potatoes, corn, dry beans, tomatoes, turnips and apples (61).

Soil properties in the Beka'a are variable, but the major arable land lies in the central parts. Most of the soils in central Beka'a are red clays. A great part has black soils which are very clayey and generally calcareous. Light chestnut soils are common and are less clayey than dark soils, but generally calcareous too. The occurrence of dark chestnut clayey soils is also common. Along the Litani river, in central Beka'a, some young alluvial soils occur. They are variable in characteristics, but have high calcium carbonate content as an only constant property. In the western part of central Beka'a, formed on white marls, strips of white greyish soils known as greyish or white rendzinas are found (23).

The study was carried out with the following objectives:

1. To determine some of the physical and chemical properties of soils of the central Beka'a and their relationships to soil classification.

2. To determine the relationship between available nutrients in the soil, as determined by soil tests, and soil classification.

REVIEW OF LITERATURE

Physical and chemical properties of soils are of major importance to progressive agriculture. A knowledge of the physical and chemical properties is a basis for the classification of soils. The fertility status is largely a result of the physical and chemical characteristics of soils.

A. Properties of Soils of the Middle East

A chemical and physical study was reported by Billaux (8), on the soil of Bhanine Station on the coast, in the north of Lebanon. The soil is sandy clay with a slightly permeable heavy clay pan, deep underneath. From the chemical point of view, the soil is calcareous and slightly alkaline. It is low in organic matter, phosphorus and potassium contents. In a report on the Hermel region in the north Beka'a, made by Billaux, et al. (9), the soils in general were found to be clayey and calcareous. The percentage of exchangeable potassium content, expressed as K_2O, ranged from medium to high (0.011-0.043 percent). The available phosphorus, expressed as P_2O_5, averaged 0.032 percent, which was relatively high on soils with low calcium carbonate content, and averaged 0.005 percent, which was relatively low on highly calcareous soils. An average of 2.6 percent of organic matter was found for these soils.

An experiment was run in the Beka'a to determine some of the minor element deficiencies on some soil types. It was found that greyish white and red soils responded to application of iron. In the case of manganese, deficiency might exist in greyish white and light chestnut soils, while in red and black soils, only slight deficiency was noted. Copper was found deficient in black soils, while zinc deficiency was not serious in any of the four soil types, but might exist in greyish white and black soils. It should be noted that the study was based on visual response by wheat and no yields were reported (4).

An experiment was reported by Khan (31), in which plant response was correlated to soil analysis. It was found that the soils of the Beka'a were very low in phosphorus, low in nitrogen, but adequate in potassium.

Also, it was noted by Adams and Sayegh (1), that soils in the Beka'a were generally very low in phosphorus, low in nitrogen, but not deficient in potassium.

Reifenberg (48), made an extensive study on the soils of Palestine. He studied the influence of climate and parent material on soil formation, the composition of clay fraction under various climatic conditions, and the base exchange and hydrogen ion concentrations of these soils.

B. Method of Analysis

Color

As designated by Pendleton and Nickerson (41), pedologists and soil surveyors have color of the soil as one of the most obvious characteristics. Relatively slight differences in the color or color pattern of only one horizon in the profile may, at times, be significant in classifying soils into one or the other of what are believed to be different groups. It is generally realized that the soil color is an indication of something which has happened to the soil and in the process may have developed or modified important soil characteristics. The color may indicate early stages of an altered soil condition which will, in the long run, profoundly affect the nature and agricultural values of soil. Obviously, then, the description and identification of soil colors must be as precise as possible.

Hutton and Rice (25), of the Color Standards Committee of the American Soil Survey Association, devised a method for measuring the color of the soil by comparison with a rotating disc composed of segments of black, white, red and yellow paper. The soil was held either in a dish or on a broad spatula. Shaw (59), had improved the method, by having the soil "mud" painted on a white blotting paper, using a brush, and then mounted on the soil colorimeter, i.e. the rotating disc with the colored segments.

Since many uncertainties and confusion often arise through personal differences regarding the estimation and description or naming the color of the soil, standardized common color names and Munsell color standards have been adopted by the U.S. Soil Survey. This is a great advance, since the precise color designations possible by the use of letters and figures, for example 10YR 5/4, are comprehensible in any occidental language without the need for translation.

For the Soil Survey, the Munsell color chip standards are mounted in a compact pocket notebook. Because of the physiological and psychophysiological limitations of color vision, and to make more effective use of these standards in specifying small differences in soil color, another form of this soil color chart, with a greater range of colors, with holes between samples, and supplied with masks, has now been developed and made available. This special form of chart includes all color chips that appear on the regular edition, and it uses the same nomenclature (41).

Mechanical Analysis

As stated by Kilmer and Alexander (33), mechanical analysis yields fundamental data that are indispensable to the proper study of the classification, morphology and genesis of soils. By means of mechanical analysis the particle size distribution is placed on a quantitative basis. The accumulation or loss of clay from soil horizons is made more apparent, and determination of the relationship of parent material to the solum is greatly facilitated. Information regarding the physical properties of soils and related to permeability, water retention, plasticity, aeration, base exchange capacity and tillage is obtained.

As pointed out by the above authors, the use of 0.2N hydrochloric acid treatment, removes the exchangeable bases and soluble salts, which might later interfere with dispersion; also it decomposes the carbonates. But Bodman et al., as reviewed by the mentioned authors, found that such treatment may be unnecessary and even objectionable for calcareous soils. The principal objection to the acid treatment is that particles of limestone, dolomite and precipitated carbonates are removed and, where large amounts of these materials are present, the textural classification of the soil may be considerably altered.

Thus this acid pretreatment depends upon the object of the analysis, the nature of the soil, and the dispersing agent employed (33).

As organic matter acts as a cementing agent between the particles, its removal is of vital importance for soil dispersion. Baver (6), working with Ohio soils, reported an increase in clay content as soils were treated with hydrogen peroxide for the destruction of organic matter. Beale (7), concluded that hydrogen peroxide treatment could be omitted for routine analysis of most lateritic soils. The organic content of soils that he studied ranged from 0.33 to 2.62 percent.

Thus the removal of organic matter depends on the amount present and the subsequent treatment employed; also it depends on the amount and kind of clay.

Dhawan et al. (18), working with Indian calcareous soil, drew the following conclusions from the results of investigations about different methods of dispersing calcareous soils: (a) sodium hydroxide, sodium oxalate, sodium silicate international method, or ammonium carbonate cannot disperse the soils to their maximum values. (b) The dispersion of calcareous soil or other soils can be successfully carried out by any one of the following dispersing agents in their order of merits; (i) sodium metaphosphate plus alkali or (ii) trituration with wet sand or (iii) sodium pyrophosphate plus alkali. (c) The maximum dispersion of calcareous soils by sodium metaphosphate or sodium pyrophosphate is most probably due to the protective action of the gelatinous substance presumably $Ca(PO_3)xH_2O$, being precipitated on calcium carbonate surfaces. (d) The physical method of trituration with wet sand, not only removes the cementing agents from the soils, but also disperses the finer fractions of the soils to their maximum limit.

Kilmer and Alexander (33), in their review of methods of mechanical analysis, discuss the elutriation, decantation, centrifugation, plummet, hydrometer, and pipette methods. Sharma and Tamhane (58), made a comparative study of the hydrometer and international pipette methods of some Indian soils. The results obtained by the two methods showed good proximity, and the hydrometer method can be safely used as a rapid and routine method for mechanical analysis of soils except those rich in organic matter and calcium carbonate content. In the latter cases, the soil should be pretreated with hydrogen peroxide and hydrochloric acid to destroy the organic matter and calcium carbonate. The time required by the hydrometer method is very short as compared to that of the pipette method and a large number of samples can be handled per day. Its simplicity and rapidity make the hydrometer method a valuable tool for routine mechanical analysis.

Khanna et al. (32), in a comparison of the hydrometer and international pipette methods for mechanical analysis of some alluvial soils of Wattar Pradesh in India, reported the same findings as those of Sharma and Tamhane. Black (10), suggested the destruction of soil organic matter, before an accurate hydrometer is used, for abnormal density in the material in suspension will occur, and thus erroneous values will result. He also found, that in the absence of organic matter, determinations of silt were likely to be less accurate than those of clay, both on account of greater variability of particle density and greater experimental error.

Percent Aggregation

In measuring the degree of aggregation of silt and clay (less than 50 microns) fraction, the Bouyoucos dispersion method was used. It measured the concentration of two suspensions of the same soil, one of which was dispersed by any standard dispersion procedure to give total silt plus clay. The other suspension, prepared by mild (end-over-end) agitation of the sample in water, gave a measure of the unaggregated silt plus clay. The difference in concentration between the two suspensions provided a measure of the amount of silt plus clay particles that was bound into water stable aggregates larger than 50 microns in size (63).

<u>Bulk Density</u>

Bulk density is defined as the mass or weight of a unit volume of oven dry soil; thus this volume would include both solids and pores.

In the field, the bulk density of a soil may be estimated by driving a cylinder of known volume into the ground and thus obtaining a core of natural soil.

Different soil sampler cylinders were devised for obtaining an undisturbed soil sample; Coile (15), Yoder (66), were among the first to design a soil sampling cylinder. Later, Dortignac (19), Lutz (34), and Jamison et al. (28), made some improvement on the design, by either using a jack, pressure or a hammer to force the cylinder into the soil.

However, the determination of the volume of soil clods in the laboratory, had been substituted for the bulk density in the field. The method had been applied to the study of plowsoles and to sub-soil development. It was also planned to include it as a routine procedure for the official soil survey samples as studied in the laboratory (43).

Perry (43), in 1942, had devised a simple rapid method of determining the apparent density of soil aggregates. The method suggests drying the clod at 100-110^{o}C to constant weight; then coating it with parafin wax; and finally inserting the coated clod into sets of jars containing solutions of zinc chloride of decreasing densities respectively; the density of the coated clod in question will be that of the lowest density in which it floats.

Later in 1944, as mentioned by Johnston (29), a more accurate method of determining volume of soil clods was devised. It involved the use of a soil volumeter, where the paraffin coated clod was placed in one side of the soil volumeter, and the density was read on the other side on a burette by a difference of two readings on the burette i.e. first reading without the clod inserted, second reading, with the clod inserted.

Clay Fraction

In the separation of clay fractions, Piper (44), discussed two methods, the sodium chloride method and the Puri's ammonium carbonate method. In both methods the separation was accomplished by decantation.

Kilmer and Alexander (33), reported the pipette method which is more standard than any of the centrifuge, decantation and Hydrometer methods.

pH

pH or hydrogen ion concentration is of major importance to soil scientists. It has great influence on the chemical and physical properties of soils. It influences the availability of most elements in the soil, which in turn are of great need for plant growth.

Reed and Cummings (47), discussed the methods for determining soil reaction; they were divided roughly into two classes, electrometric and colorimetric.

In the electrometric methods an electrode, the potential of which was a direct function of hydrogen-ion concentration, was immersed in a solution or suspension, connected with another standard half-cell was measured potentiometrically.

Mason and Obenshain (35), in their paper of comparison of methods for the determination of soil reaction, found that the glass electrode method proved to be more accurate than the quinhydrone electrode method, especially at pH 8.5 and above, where it was not applicable because of the chemical oxidation of the hydroquinone component.

In the colorimetric methods, different dye indicators, which operate at different ranges of pH, were used on clear extracts and then pH determination was by comparison with a color chart or with standards using some type of comparator. The use of these methods could be helpful where electrometric methods are impractical and where a range of 0.2 to 0.3 unit in pH is accurate enough to be of use.

The pH value of soils is affected by dilution. The pH of a certain soil would differ greatly at soil-water ratio of 1:1 from that at a ratio of 1:10. A ratio of 1:2.5 was adopted by the International Society of Soil Science in 1930.

Keaton (30), points out that these higher dilutions have been used both because of the type of apparatus for measuring H-ion concentration and because of the reproducibility of the pH value at higher dilutions.

As pointed out by Reed and Cummings (47), there is much controversy on whether pH determination should be done at moisture equivalent or at high soil-water ratio.

According to Bailey (5), agitation of the suspension during the determination with the glass electrode is essential for reliable results, especially with coarse-textured soils.

McGeorge (36), found that the base-adsorption complex contributes to the pH of the soil by hydrolysis; therefore the magnitude of its influence depends upon the nature of the adsorbed bases and the activity of the water in contact with the soil.

Cation Exchange Capacity

The cation exchange capacity and the amounts of different exchangeable cations present in the soil are of great indispensability in most studies dealing with the chemical physical behavior of the soil or with soil fertility. Effective methods for the reclamation of sodic soils have been investigated on the basis of cation exchange capacity. Also through studies of cation exchange, soil acidity has come to be much better understood, and practical means for its control havebeen developed. Cation exchange has an important bearing on physical and microbiological processes of soils and on availability of plant nutrients.

Schollenberger and Simon (56), discussed different procedures for determining exchange capacity and exchangeable cations. Exact equivalence cannot be expected by all methods. It is necessary to select some definite pH as the point of reference or "neutrality". As to what this point should be, there are differences of opinion as stated by the above authors. Some consider pH 8.4 the proper reference point, because it is the pH of equilibrium in the system calcium carbonate-water-carbon dioxide at the partial pressure of the atmosphere . But there seem to be equally cogent reasons why pH 7 should be the point of reference, entirely aside from the fact that it is the conventional "neutral point". This is near the pH of the bicarbonate-carbonic acid buffer system at partial pressures of carbon dioxide likely to prevail in the atmosphere of a fertile soil during the season of active growth.

However, it was found logical to use a solution of a neutral salt , for the determination of exchange capacity and exchangeable bases . Both acid and base of the salt should be weakly dissociated . A common salt that seems to meet most of the requirements is ammonium acetate. Prianishnikov , as mentioned in this paper , appears to have been the first to use ammonium acetate for estimating exchangeable bases in soils , but his paper was generally overlooked prior to a publication by Schollenberger and Simon (56). This salt has in its favor the facts that ammonium is never naturally a major soil base but can function as such under laboratory conditions and is easily determinable, and the acetates of all soil bases are readily soluble. Moreover, a great analytical advantage is that it is almost completely volatile at comparatively low temperature. A pure solution of it can be prepared easily from inexpensive reagent chemicals. About its only defects in application to base-exchange work on soils are the difficulty in titrating the excess acid or base in a large volume of strong solution, and its solubility effect upon calcareous material, and its fixation in soils. Dharival and Stevenson (17), in a study on the determination of ammonium fixation in soils, found that the ammonium fixing capacity of a soil is more where the predominant clay mineral is illite, while it is less where the predominant clay mineral is montmorillonite.

Exchangeable Cations

Viro (64), used ethelyne-diamine-tetra-acetic acid (EDTA) as extracting agent for adsorbed ions. He found that it is more effective extracting agent than ammonium acetate, also it gives a good recovery for the cations studied, and certain anions can be determined. But the (EDTA) method is applicable for determining the content of exchangeable nutrients in acid soils, for on calcareous soils, it is hardly suitable because EDTA can dissolve water-insoluble carbonates that are not part of the exchange complex.

According to Bower et al. (12), exchangeable cations are extracted by ammonium acetate, pH 7; while total cations are extracted by sodium acetate, pH 8.2. Ensminger (21), showed that in using barium acetate as extracting agent for exchangeable bases, there was no need to wash out the excess saturating solution as in the case of ammonium acetate solution, where it was necessary to wash the excess solution. It also gave higher results, used at pH 7, than the ammonium acetate method.

Fieldes et al. (22), estimated the exchangeable cations of more than four hundred samples, including selected samples of different soil types by the Beckman flame spectrophotometer. The method is considerably faster than chemical methods and quite reliable. It is now an established routine method in most laboratories.

Rogers (50), determined exchangeable bases with the air-acetylene flame and quartz photo-electric spectrophotometer and found that the analysis was quite rapid with high accuracy.

Pratt and Bradford (45), used the Beckman model B flame spectrophotometer. They found that the exchangeable calcium and magnesium as determined by this method agreed well with results of chemical methods. Exchangeable sodium and potassium, as determined by these methods described, agreed well with values found with the Perkin Elmer flame photometer using lithium as internal standard.

Peng and Chu (42), compared the Williams method of determining total exchangeable bases of soils with the soxhlet apparatus method. The latter was found to be simple, more reliable, and less time consuming than the Williams method.

Total Nitrogen

In the determination of total nitrogen, Prince (46), stated that the Kjeldahl method had long been the standard procedure. Various modifications for increasing the rapidity or simplicity of the determination had been introduced from time to time, but the fundamental principles still apply. The organic matter in the sample was oxidized by boiling with concentrated sulfuric acid in connection with a catalyst, or a salt that had been added to raise the boiling point of the mixture, or both, to speed the reaction. Organic nitrogen was converted to ammonia and fixed in the digestion solution as ammonium sulfate. The ammonia was released from this solution by the addition of excess alkali and was distilled over into an excess of standard acid. The excess standard acid was titrated with a standard alkaline solution, using a suitable indicator.

A recent method using perchloric acid (0.5ml. of a 35 percent grade), after a preliminary 10-minute vigorous boiling with concentrated sulfuric acid and selinium oxychloride, reduced the digestion time to about 30 minutes.

Emmert (20), reported in an earlier publication a rapid method for determining total nitrogen in soil by oxidation to nitrate, it was found that the amide nitrogen and ammonia nitrogen were not oxidized and total nitrogen was not determined in soil that contained these forms. Later a modified process was proposed where amide nitrogen washydrolyzed to ammonia and the ammonia nitrogen was combined as glycine by means of monochloracetic acid, the amino acid group being readily oxidizable to nitric acid so as to be included in the phenoldisulforic estimation of nitrate nitrogen colorimetrically.

The method was satisfactory on the soils studied, but it had not yet been tried on a very wide range of soils.

Organic Matter

Organic matter varies considerably in different soils as to amount and chemical composition. It affects the chemical and physical characteristics and productivity of soils. Thus, much work has been done on its determinations.

As suggested by Browning (14) and Piper (44), the dry combustion method is probably the most reliable method available at present for determining the organic matter content of soils.

Also Browning (14), compared the dry combustion method with the rapid dichromate titration method for determining organic matter in soils. It was studied on fifty soils and it was found that, after correcting the rapid titration method by an appropriate factor, certain soils still showed considerable variation from the data obtained by the dry combustion method. However Allison (2), indicated that there was an excellent agreement between the two methods of analysis.

Smith and Weldon (60), compared some methods for the determination of soil organic matter; Schollenberger's titration method (52), (53), (54), modification of Robinson's hydrogen peroxide method, wet combustion method and modification of Walkely-Black method (65). The comparison was studied on 158 samples. High correlation was found between the results from the rapid methods and those from the modified Robinson's method and wet combustion procedures, with the exception of the samples to which organic material had been added recently. The rapid methods were found to be efficient on calcareous soils; while Robinson's could not be used successfully. The wet combustion needed both total and inorganic carbon measurements. The rapid methods were found to be economical in both time and chemicals.

Available Phosphorus

Bray and Kurtz (13), discussed the different forms of available phosphorus. Recent work showed that when acids or acids buffered to definite pH values have been used as extractants, they extracted easily acid-soluble forms more or less effectively, but were less effective in extracting the adsorbed forms except where these were present in large amounts. In removing the adsorbed forms of phosphate and separating them from the acid-soluble forms, neutral ammonium fluoride was the suggested reagent (13).

As mentioned by Bray and Kurtz (13), the only important difference between methods for determining available forms of soil nutrients and the usual quantitative methods for any particular element lies in the extracting solution.

Miller and Axley (37), compared various chemical methods for available phosphorus with crop response. They summed up that in a number of instances there was little difference between the correlation coefficients for the various chemical methods. However, the method employing sulfuric acid and ammonium fluoride as an extractant apparently showed the closest relationship with crop response. The Bray and Kurtz No 1 and sodium bicarbonate methods gave the next best relationships with crop response and were both about equally satisfactory for determining available phosphorus in the soils.

Olsen et al. (38), suggested the use of sodium bicarbonate at pH 8.5 as the extracting solution for available phosphorus. The method proved to be adapted best to calcareous soils. The method was also adaptable to rapid, routine soil-testing procedures.

Oommen et al. (39), made a comparative study of available phosphorus on Indian soils. The methods they discussed were: (a) Dyer's method-1% citric acid, (b) Das's method-1% potassium carbonate, (c) Truog's method-N/500 sulfuric acid, pH adjusted to 3.0, and (d) Olsen's method-0.5 molar sodium bicarbonate, pH adjusted to 8.5. In general, there did not appear to be any relationship between the total phosphate and the available, as estimated by these different methods. On a soil type basis, there was a significant correlation in red and lateritic soils between Dyer's and Das's and between Olsen's and Das's methods. There was no significant correlation between any two methods in alluvial soils. On a pH basis, there was a significant correlation between Olsen's and Das's methods in acid soils while there was no significant correlation between any two methods in alluvial soil. In soils of low base exchange capacities, there was a significant correlation between any two methods except between Truog's and Dyer's and Truog's and Das's methods while in soils of high exchange capacities, there was no significant correlation except between Das's and Truog's methods. Considering all soils together, the values obtained by Das's correlated well with Dyer's method and to some extent with Olsen's method. Truog's method showed no correlation with Olsen's and Das's methods.

Saunders (51), suggested the use of hot 0.1N sodium hydroxide for extraction of available phosphorus from tropical soils, particularly red earths, where phosphorus is retained in strongly absorbed forms. Good correlations were obtained between analytical data and field responses for a variety of soils in different localities. The use of 8(OH) Quinoline and selenious acid as suggested by Ghani and Islam (24), in the determination of chemically available phosphorus were critically investigated with reference to some lateritic soils of high fixing capacity. Truog's method and the acetic acid method were included in the study of comparison. A combination of the two was also investigated. It was shown that the combination treatment reduced the percentage fixation to a very low level. Thus it was concluded that 8(OH) Quinoline and selenious acid in acetic acid gave the most satisfactory results for the chemically available phosphorus in soil. Datta and Kamath (16), proposed a new method for extraction of available phosphorus in soils. They used 0.1 percent versene solution made 0.03N in respect of fluoride. It gave good correlation with the 0.5M sodium bicarbonate method.

Carbonates

Generally in soils carbonate is determined and reported as calcium carbonate, even though it may be partly dolomitic, some of the calcium being replaced by magnesium.

Schollenberger (55), reported the method where carbon dioxide evolved from carbonates on boiling the sample with dilute hydrochloric acid containing ferrous chloride, below 30°C in an evacuated apparatus, was absorbed in excess standard barium hydroxide solution under conditions ensuring complete absorption, and the excess barium hydroxide was titrated in the presence of the precipitated carbonate. Schollenberger stated that if the temperature was high, production of carbon dioxide would occur by decarboxylation of the organic matter; also if the hydrochloric acid was too concentrated. He also noted that some organic matter was readily oxidized in those soils containing manganese dioxide. He avoided errors from this source by adding ferrous chloride to dilute hydrochloric acid used and decomposing the carbonates at a low temperature i.e. boiling under reduced pressure. As mentioned by Piper (44), Shaw used stannous chloride for a similar purpose. Ferrous chloride was not quite as effective as stannous chloride but, for practical reasons, it was preferred. Its solution was more convenient to prepare and did not foul the apparatus like stannous chloride.

Piper (44), discussed a rapid titration method, where the soil was treated with an excess of hydrochloric acid, and the excess acid was titrated with sodium hydroxide using bromo thymol blue as indicator.

Silica Sesqui-oxide Ratio

In determining the silica sesqui-oxides, many methods have been devised for extraction; for example, Robinson (49) used the fusion method with sodium carbonate; Jackson (27) described the use of perchloric acid for digestion, also as an alternative the use of hydrofluoric acid, as digestion. Also at the French chemical laboratory at Bondy (26), they used a tri-acid method for digesting the soil.

In determining the amount of SiO_2, Al_2O_3, and Fe_2O_3 different methods have been devised which are found in A.O.A.C, (3), Jackson (27), and Piper (44).

But as a comparison between these methods, no work could be cited, or at least no work was available to us.

DESCRIPTION OF THE SOILS

The Beka'a plain ranges in altitude from 600 to 1100 meters, and has warm and dry summers, while the winters are usually cold. Rainfall, occurring during the period from October to April, averages about 550 mm. in the central Beka'a.

Soils of six different categories were selected in the Beka'a plain according to the soil map (23):

a. Red soils or terra rosa

b. Recent alluvial soils

c. Greyish white rendzina soils

d. Black or grey soils

e. Dark chestnut soils

f. Light chestnut soils

a. Red soils or terra rosa

These soils are transported clays, and approach somewhat the tropical red clays, in which the ferric oxides are the cause of the general color.

Besides the clayey portion of these soils, it is commonplace to observe varying percentages of crushed residues comprising silicaceous sand and silicaceous or calcareous fine gravel, which often times modify to a great extent their characteristics. Depending on the climatic zone in which they lie, these soils are generally considered to be agriculturally satisfactory.

b. Recent alluvial soils

Though found in many areas in Lebanon, these alluviums occur in the central Beka'a mainly along the Litani river. These deposits are young and reflect different characteristics of local conditions.

Along the periphery of the central Beka'a, these alluvial soils harbor a high percentage of gravel which in some cases attains stone size. The high calcium carbonate content (20 to 60 percent total calcium carbonate) is the only common characteristic of these soils.

c. Greyish white rendzina soils

Occurring on a parent material of soft white marl, these soils merge with the lower horizon undifferentiated. Consequently, the different horizons of these soils cannot be distinguished except occasionally where vegetative debris may be found. These soils are high in calcium carbonate content.

d. Black or grey soils

Found in some parts of the central Beka'a, these soils occur in the same climatic zone as the red soils, although requiring a different set of factors for their formation.

The parent material is made of alluviums or colluviums, apparently cleaved from white marls found at higher elevations. These soils are clayey in general and high in calcium carbonate content. The black color is due to the humus.

e. Dark chestnut soils

These soils are generally clayey. The specific color results probably from the mixture of red colluvial soils, exposed at the foothills of the mountains of Lebanon and Anti-Lebanon, and the light chestnut soils described below.

These soils, normally dark, seem to exist in zones of low rainfall.

f. Light chestnut soils

Generally, these soils occur in the central Beka'a, in areas away from the foothills. Their clay content is less than the dark chestnut soils. They are generally calcareous but sometimes decalcified.

In northern Beka'a, these soils are mixed with red soils resulting in lighter chestnut shades.

METHOD OF SAMPLING

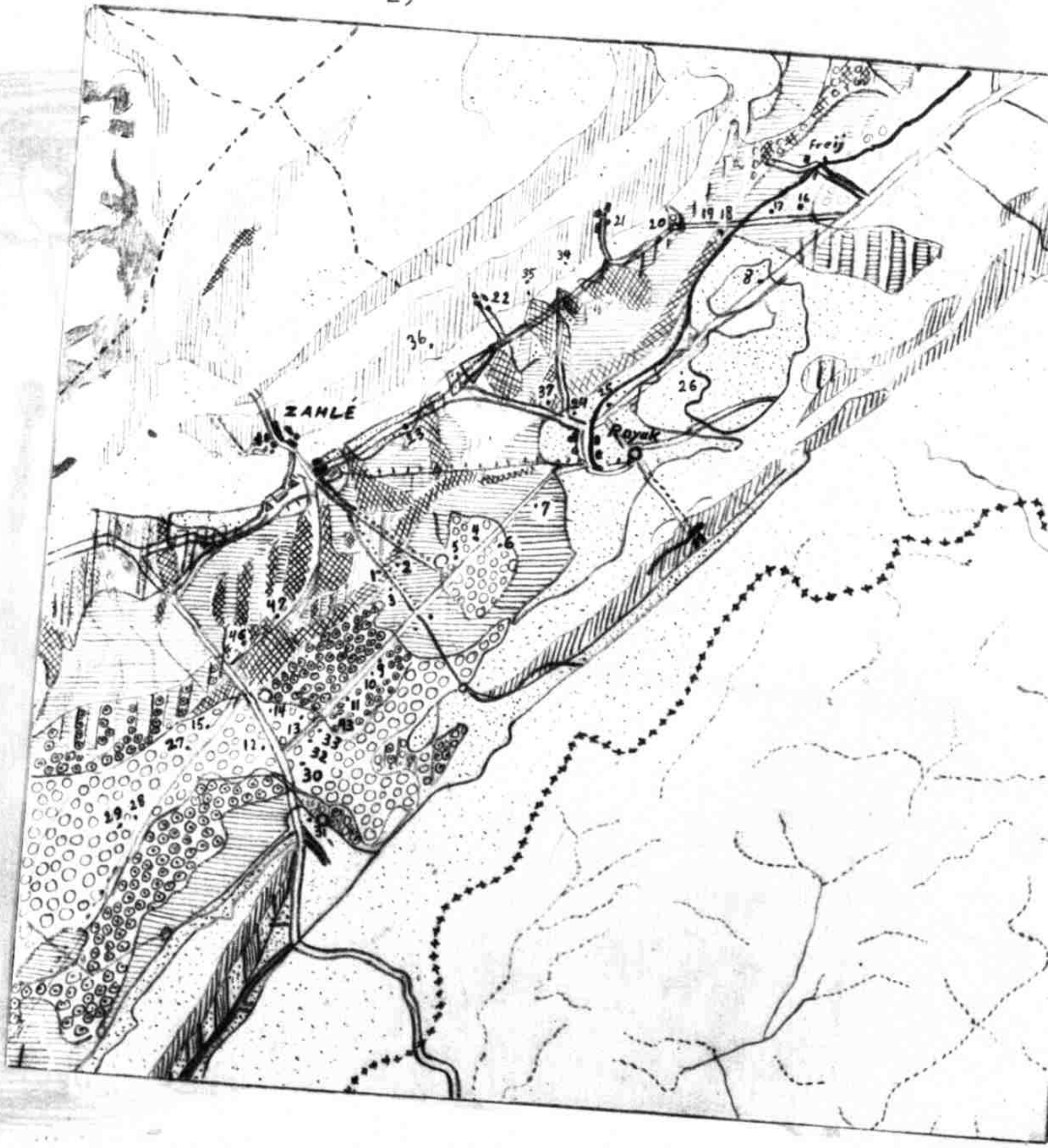
The analysis can be no better than the sample (27). The very challenging soil sampling problem has been summarized by the Association of Official Agricultural Chemists (3), as follows:

> "In view of variability of soils, it is difficult to devise an entirely satisfactory method for sampling. It is obvious that details of procedure should be determined by purpose for which sample is taken."

The area under study was observed in relation to the soil map (23). Each sampling site was first determined as being characteristic of the area. Then it was located on the map, by the use of the mileage meter of the car, taking as a reference point either a crossroad, a hill or a stream, etc.

Samples from each of seven sites were collected from the red and light chestnut soils, while samples from six sites were collected from each of the recent alluvium, greyish white and dark chestnut soils. Twelve samples were collected from the black soil, but were divided, according to their color, into six black and six grey soils. The sampling sites were selected from different locations for each category, as shown by the attached map Fig. 1.

A brief history of the land was recorded, when possible, i.e. what crop was grown, if the land was cultivated, fertilized or irrigated, etc. Then each spot



Red

White rendzina

Recent alluvial

Light chestnut

Dark chestnut

Grey or black

Figure I. Soil map showing the sampling sites locations in the Beka'a area.

was cleaned from plant residues and debris with a spade. A hole was dug, exposing the top and subsoil profiles. Each surface soil, 0-6 inches deep, and subsoil 8-12 inches deep, was sampled separately and put in a paper bag. Each bag was given a number referring to the spot and soil profile. The soil color was determined on the spot by the Munsell soil color charts. The samples were air-dried in the laboratory. They were then ground and passed through a 2-mm. sieve, and stored in air-tight glass jars. Some clods were left intact for the determination of bulk density. The percentage of gravel and stones was also determined.

METHODS OF ANALYSIS

The choice of the analytical method for any given determination depends upon many factors. Accuracy and reproducibility are of major importance in selecting the method.

Chemical Analysis

pH

The pH values of the soils were determined on 1:2.5 soil-water suspension using a pH meter with a glass electrode.

Calcium carbonate

The alkaline earth carbonate determination was carried out by a rapid titrimetric method (44). The time was reduced to fifteen minutes, with constant shaking on a mechanical shaker. The solution was then filtered and titrated.

Organic matter

The percentage of organic matter was determined by (a) the dry combustion method (43), and (b) by the dichromate titration method as modified by Walkley and Black (43), except that orthophenanthroline ferrous sulfate (ferroin) was used as the indicator.

Total nitrogen

The determination of nitrogen was done by the Kjeldahl method as modified by Winkler (44), with the use of potassium sulfate, copper sulfate and ferrous sulfate as the digestion mixture.

Available phosphorus

Analysis for available phosphorus was determined by methods suggested by (a) Olsen et al., using sodium bicarbonate pH 8.5 as extractant (38), and (b) Bray and Kurtz No.1, 0.03 N ammonium fluoride in 0.025 N hydrochloric acid as extractant (27).

Cation exchange capacity

The cation exchange capacity was determined by extracting with sodium acetate as suggested by the U.S. Salinity Laboratory (63). The sodium concentration was then determined photometrically by the use of the Beckman model D. U. with flame photometer attachment.

Determination of exchangeable cations

The exchangeable potassium and sodium were determined in an ammonium acetate extract using the Beckman model D. U. flame photometer (63).

Exchangeable calcium plus magnesium was calculated by subtracting the sum of exchangeable sodium and potassium from the cation exchange capacity.

Determination of the silica sesqui-oxides

Oxides of silica, iron and aluminum were determined gravimetrically (57).

Physical Analysis

Moisture content

The percentage of the moisture content was determined by taking one hundred grams of soil and drying at 105° C to a constant weight. From the loss of weight the moisture percentage was calculated.

Mechanical analysis

The percentage of sand, silt and clay was determined by the Bouyoucos method, using sodium hexametaphosphate as the dispersing agent (11). The soil textural class was determined by the triangular graph (44).

Clay fraction less than 0.2 microns

The percentage of clay fraction less than 0.2 microns was determined by the pipette method. This clay fraction was separated by the use of a centrifuge. A 25-ml. Lowy pipette was used to pipet the suspension which was then dried in the oven to a constant weight (33).

Aggregate analysis

The percentage aggregation was determined as suggested by the U. S. Salinity Laboratory (63).

Bulk density

The bulk density was determined as suggested by Johnston (29), with the modification that the paraffined clod was immersed in water and weighed. The apparent loss in weight was equal to the weight of water displaced. The volume of the clod plus paraffin was then calculated by use of the density of water at the temperature of determination and the weight of water displaced by the clod and paraffin. The volume of paraffin was calculated from its density and weight. The volume of soil was then obtained by difference.

Statistical Analysis

Differences in soil property determinations between all soil mapping units were tested by the analysis of variance for all chemical and physical tests run, except for the tests for silica sesqui-oxides and clay fraction less than 0.2 microns.

Statistical significance was determined between soil categories at the 5 percent level using the formula:

$$\text{Critical difference} = t_{5\%}\sqrt{S_o^2\left(\frac{1}{n_1}+\frac{1}{n_2}\right)}$$

where t = "t" value from table with degrees of freedom corresponding to S_o^2

S_o^2 = Error mean square

n_1 = Number of samples in soil category (1)

n_2 = Number of samples in soil category (2)

Correlation between the organic matter methods and between the available phosphorus methods were determined according to Panse and Sukhatme (40), i.e. finding the correlation value "r".

RESULTS AND DISCUSSION

Results of the physical and chemical analyses of the soils are presented in Tables I, II, V and XV. Tables I and II embody the results of the physical analysis of the surface and subsoils, while Tables V and XV comprise the results of the chemical analysis of the surface and subsoils.

It was observed that there was no statistical significance between the surface and subsoil for all the physical and chemical properties determined, but there existed some differences between them.

From Table I, it was noted that all soil categories of both surface and subsoils were clayey in texture, with a higher amount of clay in the surface soil than in the subsoil for all soil categories. Figure II, shows the percentages of sand, silt and clay of each category of the surface soil.

The percentage of stones and gravel ranged from 4.5 to 19.1 percent in the surface and 4.4 to 19.4 percent in the subsoils.

The percentage of clay fraction less than 0.2 microns is shown in Table II. It was an average value of three surface soil samples in each soil category as shown in the appendix (Table XVI). The percentage of clay fraction less than 0.2 microns was high for soil categories which had high amount of clay, and decreased as the percentage of clay decreased. It ranged from 11.4 to 24.2 percent

Table I. Average values of the physical analysis of the surface and subsoil from the central Beka'a area.

Soil Category		Stones & Gravel Percent	Sand Percent	Silt Percent	Clay Percent	Texture	Aggregation+ Percent	Bulk density gr/c.c.	Moisture content Percent
Red soils (terra rosa)	T	11.5	23.34	17.84	58.82	clay	81.0	1.76	7.20
	S	12.2	26.27	22.44	51.29	clay			7.40
Recent alluvial soils	T	12.3	18.10	25.33	56.57	clay	84.2	1.57	6.28
	S	12.7	16.10	27.96	55.94	clay			6.32
White rendzina soils	T	19.1	15.74	29.80	54.48	clay	74.6	1.62	4.24
	S	19.4	15.27	31.64	53.09	clay			4.14
Light chestnut soils	T	15.4	11.02	24.35	64.63	clay	87.6	1.55	7.14
	S	15.8	13.55	25.03	61.42	clay			7.14
Dark chestnut soils	T	4.9	12.68	20.45	66.87	clay	89.2	1.61	8.75
	S	5.1	11.75	24.63	63.62	clay			8.68
Grey soils	T	4.5	10.48	30.77	58.75	clay	76.6	1.44	6.28
	S	4.4	8.81	33.92	57.27	clay			6.24
Black soils	T	7.3	8.73	27.00	64.27	clay	85.6	1.64	9.31
	S	7.1	8.26	29.16	62.58	clay			9.30

T = Top soil
S = Subsoil

\+ Aggregation of particles less than 50 microns expressed in percentage.

Table II. Average values of three soil samples of the clay fraction less than 0.2 microns of the surface soil from the central Beka'a area.

Soil Category	Clay fraction less than 0.2μ percent of clay	Clay fraction less than 0.2μ percent of soil
Red soils (terra rosa)	15.0	8.3
Recent alluvial soils	14.5	8.4
White rendzina soils	11.4	6.4
Light chestnut soils	24.2	15.7
Dark chestnut soils	18.6	12.8
Grey soils	14.0	8.3
Black soils	22.8	15.7

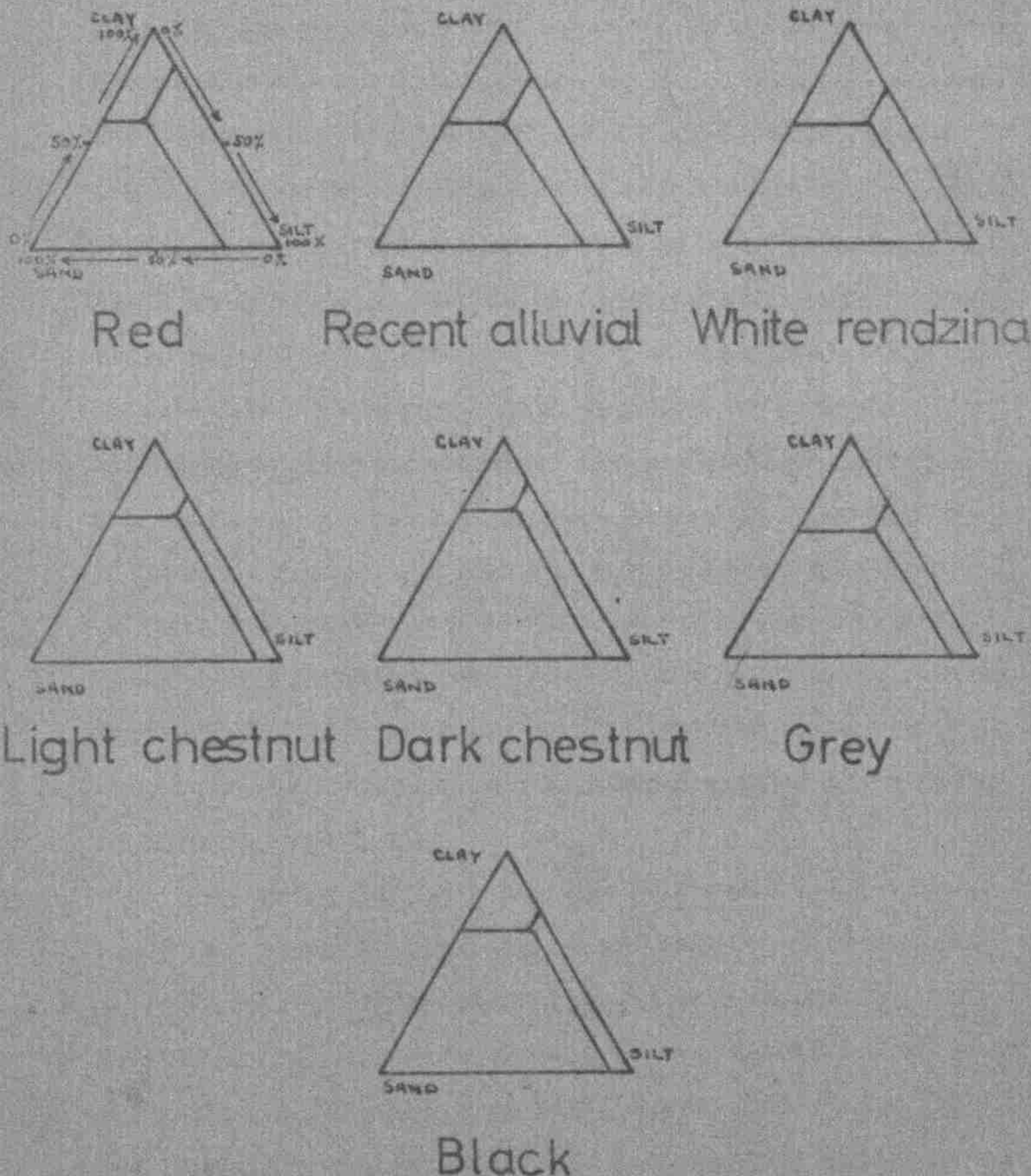


Figure II. Percentages of sand, silt and clay of the seven soil categories.

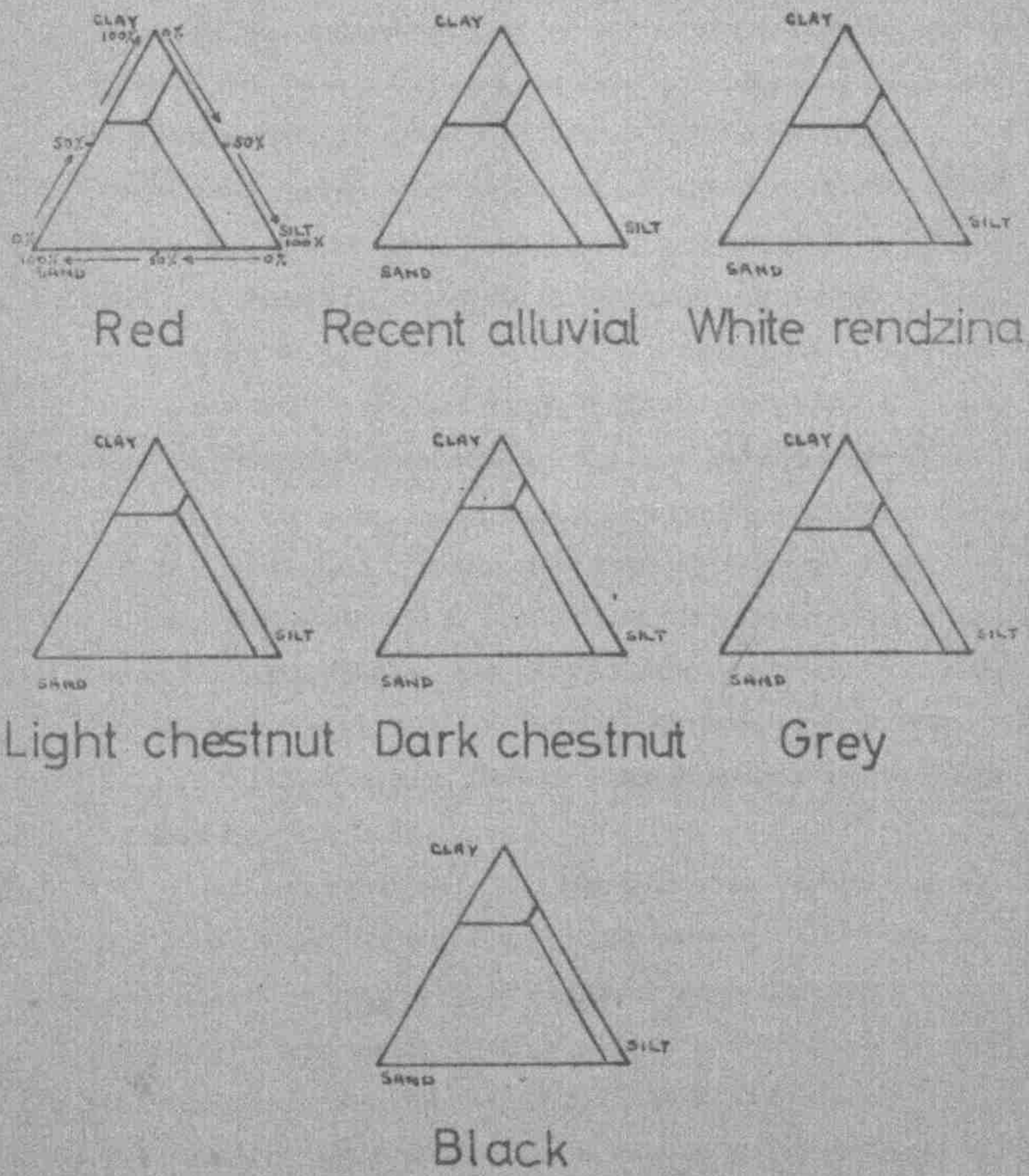


Figure II. Percentages of sand, silt and clay of the seven soil categories.

of the total clay and 6.4 to 15.7 percent of the soil.

The percentage aggregation was also determined for surface soils only. It ranged from 74.6 to 89.2 percent. The aggregation is measured by difference between the weight of total silt plus clay in dispersed suspension and the weight of total silt plus clay in undispersed suspension divided by the weight of total silt plus clay in dispersed suspension, expressed in percentage . As shown in Table III, the light chestnut and dark chestnut soils were significantly more highly aggregated than the white rendzina and grey soils with the red, recent alluvial and black soils intermediate. A negative correlation of r = -0.78 was calculated between percentage aggregation and calcium carbonate content. The greater the amount of calcium carbonate found the less was the aggregation. A possible explanation, was that calcium carbonate affected aggregation indirectly in that the greater amount of calcium carbonate, the less of clay fraction and consequently less aggregation.

As shown in Table IV, the bulk density of the surface soils was somewhat high. It ranged between 1.44 and 1.76 gm./cc. It was unexpected for clay soils to have such high bulk densities; but was probably due to the compaction of most soil samples. There was no significant differences in bulk density between any of the soil mapping units at the 5 percent level.

Table III. Analysis of variance and mean values of the surface soil for aggregation percentage.[++]

Source	df	SS	MS	F
Soil Categories	6	1128.67	188.11	7.59[+]
Error	37	916.73	24.78	
Total	43	2045.40		

White rendzina	Grey	Red	Recent alluvial	Black	Light chestnut	Dark chestnut
74.6	76.6	81.0	84.2	85.8	87.6	89.2
—	—					
	—	—				
		—	—	—		
			—	—	—	—

+ Significant at the 5% level.
++ Soil categories which do not differ significantly have been underlined.

Table IV. Analysis of variance and mean values of the surface soil for bulk density expressed in grams per cubic centimeter.++

Source	df	SS	MS	F
Soil Categories	6	0.3655	0.0609	1.32
Error	37	1.7127	0.0463	
Total	43	2.0782		

Grey	Light chestnut	Recent alluvial	Dark chestnut	White rendzina	Black	Red
1.44	1.55	1.57	1.61	1.62	1.64	1.76

++ Soil categories which do not differ significantly have been underlined.

+ Significant at the 5% level.

From Table V, it was observed that the calcium carbonate content of these soils ranged from medium to high, 34.7 to 69.8 percent in the surface soil and 35.9 to 71.1 percent in the subsoil. This was in line with what was expected, because almost all soils in the central Beka'a are calcareous. It could be noted that all soil categories had slightly higher calcium carbonate content in the subsoils than in the surface. This might be due to that some weathering and leaching had occurred in the surface soil. As shown in Table VI, the white rendzina soils had the highest amount of calcium carbonate. This was expected, as suggested by the greyish white color of the soil. The grey soils were second highest in amount, which was also suggested by their color, but they did not differ statistically from the recent alluvial and black soils. The red soils had the least amount of calcium carbonate, but there was no significant difference between these soils and the dark and light chestnut soils. The same trend of grouping was observed for the subsoils as shown in Table VI.

From Table VII, it was observed that all soils in the central Beka'a were alkaline. Their pH values ranged from 8.0 to 8.3 for both surface and subsoils. The high values of pH were related to the high amounts of calcium carbonate in these soils. The white rendzina and black soils were significantly higher in pH than the red and grey

Table V. Average values of the chemical analysis of the surface and subsoil from the central Beka'a area.

Soil Category		Organic Matter dry combustion percent	Organic Matter wet Combustion percent	Total Nitrogen percent	C:N Ratio	Available Phosphorus pp2m Olsen's Method	Available Phosphorus pp2m Bray & Kurtz No. 1 Method
Red soils (terra rosa)	T	2.08	1.87	0.087	13.7	10.96	10.72
	S	2.03	1.86	0.079	14.9	8.42	8.16
Recent alluvial soils	T	4.36	4.08	0.178	14.3	9.88	9.46
	S	3.78	3.72	0.169	13.6	11.33	10.38
White rendzina soils	T	4.26	3.88	0.132	18.2	53.12	51.44
	S	4.08	3.60	0.123	18.2	52.77	50.17
Light chestnut soils	T	3.18	2.75	0.139	13.3	7.27	7.10
	S	2.89	2.58	0.130	13.0	6.70	6.67
Dark chestnut soils	T	2.93	2.65	0.127	13.7	23.87	22.16
	S	3.09	2.80	0.119	15.3	20.07	19.97
Grey soils	T	4.62	3.37	0.152	14.3	24.96	24.83
	S	3.20	2.92	0.140	13.4	23.83	23.62
Black soils	T	2.86	2.58	0.127	13.1	9.84	9.75
	S	2.61	2.47	0.117	13.1	8.90	8.86

T = Top soil
S = Subsoil

Table V. continued. Average values of the chemical analysis of the surface and subsoil from the central Beka'a area.

Soil Category		pH 1:2.5	Calcium Carbonate percent	Cation Exchange Capacity m.e./100 gm. of soil	Adsorbed Cations m.e./100 gm. of soil Ca+ Mg	K	Na
Red soils	T	8.0	34.7	41.5	40.36	0.74	0.40
(terra rosa)	S	8.0	35.9	40.8	39.71	0.71	0.38
Recent allu-	T	8.2	49.9	42.6	41.52	0.75	0.33
vial soils	S	8.2	50.1	41.8	40.76	0.72	0.32
White rend-	T	8.3	69.8	39.6	38.40	0.84	0.36
zina soils	S	8.3	71.1	39.2	38.06	0.80	0.34
Light chest-	T	8.2	37.9	52.9	51.24	1.36	0.30
nut soils	S	8.2	38.6	51.9	50.33	1.30	0.27
Dark chest-	T	8.2	36.3	53.3	52.30	0.70	0.30
nut soils	S	8.2	36.4	50.3	49.34	0.68	0.28
Grey	T	8.1	54.2	43.0	41.83	0.88	0.29
soils	S	8.1	54.4	42.9	41.79	0.85	0.26
Black	T	8.3	45.7	46.4	45.23	0.87	0.30
soils	S	8.2	46.6	45.1	44.01	0.82	0.27

T = Top soil
S = Subsoil

Table VI. Analysis of variance and mean values of the surface and subsoil for calcium carbonate content expressed in percentage.++

surface soil

Source	df	SS	MS	F
Soil Categories	6	5811.0	968.5	13.4+
Error	37	2668.7	72.1	
Total	43	8479.7		

Red	Dark chestnut	Light chestnut	Black	Recent alluvial	Grey	White rendzina
34.7	36.3	37.9	45.7	49.9	54.2	69.8

subsoil

Source	df	SS	MS	F
Soil Categories	6	5920.0	986.7	13.6+
Error	37	2692.7	72.8	
Total	43	8612.7		

Red	Dark chestnut	Light chestnut	Black	Recent alluvial	Grey	White rendzina
35.9	36.4	38.6	46.6	50.1	54.4	71.1

+ Significant at the 5% level.

++ Soil categories which do not differ significantly have been underlined.

Table VII. Analysis of variance and mean values of the surface and subsoil for pH.[++]

surface soil

Source	df	SS	MS	F
Soil Categories	6	0.43	0.072	6.17[+]
Error	37	0.43	0.012	
Total	43	0.86		

Red	Grey	Recent alluvial	Light chestnut	Dark chestnut	Black	White rendzina
8.0	8.1	8.2	8.2	8.2	8.3	8.3

subsoil

Source	df	SS	MS	F
Soil Categories	6	0.43	0.071	7.89[+]
Error	37	0.32	0.009	
Total	43	0.75		

Red	Grey	Recent alluvial	Light chestnut	Dark chestnut	Black	White rendzina
8.0	8.1	8.2	8.2	8.2	8.2	8.3

+ Significant at the 5% level.
++ Soil categories which do not differ significantly have been underlined.

soils, while the recent alluvial, light chestnut and dark chestnut soils were intermediate. In the case of the subsoils, the same trend in pH values was found.

The organic matter content of the surface soil, determined by the dry combustion method, ranged from 2.08 to 4.62 percent, while that of the subsoil, ranged from 2.03 to 4.08 percent. In the case of the wet combustion method, it ranged between 1.87 and 4.08 percent for the surface soils, while for the subsoils, it ranged from 1.86 to 3.72 percent. Results of both methods were highly correlated, r = 0.90. Assuming the dry combustion as having one hundred percent recovery, the percentage recovery of the wet combustion was 78 percent compared to the commonly used factor of 89 percent. Organic matter contents of the soils were somewhat higher than expected indicating that the general level of organic matter has come to a fairly high equilibrium level in spite of the fact that they have been under cultivation for hundreds of years with almost all vegetation removed every year. As shown in Table VIII, the red soils were significantly lower in organic matter content than the white rendzina, recent alluvial and grey soils, while the black, dark and light chestnut soils were intermediate. In the case of the subsoil, the white rendzina and the recent alluvial soils were significantly higher than the red and black soils, while the light chestnut, dark chestnut and grey soils were intermediate. On the

Table VIII. Analysis of variance and mean values of the surface and subsoil for organic matter as determined by the dry combustion method expressed in percentage.++

surface soil

Source	df	SS	MS	F
Soil Categories	6	25.6610	4.2768	10.93+
Error	37	14.4759	0.3912	
Total	43	40.1369		

Red	Black	Dark chestnut	Light chestnut	White rendzina	Recent alluvial	Grey
2.08	2.86	2.93	3.18	4.26	4.36	4.62

subsoil

Source	df	SS	MS	F
Soil Categories	6	18.3835	3.0639	9.03+
Error	37	12.5552	0.3393	
Total	43	30.9387		

Red	Black	Light chestnut	Dark chestnut	Grey	Recent alluvial	White rendzina
2.03	2.61	2.89	3.09	3.20	3.78	4.08

+ Significant at the 5% level.

++ Soil categories which do not differ significantly have been underlined.

basis of the wet combustion method, the trend of grouping differed from the dry combustion method as shown in Table IX. In the case of the surface soil, the recent alluvial and the white rendzina were significantly higher than the red soils, while the black, dark and light chestnut soils were intermediate. Also the grey soils had high amounts of organic matter, but were significantly lower than the recent alluvial soils. In the case of the subsoil, the red soils were significantly lower in organic matter content than the white rendzina and recent alluvial soils, while the black, light chestnut, dark chestnut and grey soils were intermediate. It could be noted, that the black color of the black soils is not related to organic matter content, since they were lower in organic matter than some of the other soils. Also differences in colors between the red and chestnut soils may be due to higher organic matter contents of the chestnut soils thusmasking the red color to some extent.

The total nitrogen content of the surface soil ranged from 0.087 to 0.178 percent, while that of the subsoil ranged between 0.079 and 0.169 percent. It concurs with normal ranges of soil nitrogen content. It could be noted that nitrogen content was only slightly less in the subsoil. Deep plowing, thus mixing the top with the subsoil might be a reason for this small difference in amount between the surface and subsoil. As shown in Table X, the red soils

Table IX. Analysis of variance and mean values of the surface and subsoil for organic matter as determined by the wet combustion method expressed in percentage.++

surface soil

Source	df	SS	MS	F
Soil Categories	6	23.6728	3.9455	15.52+
Error	37	9.4045	0.2452	
Total	43	33.0773		

Red	Black	Dark chestnut	Light chestnut	Grey	White rendzina	Recent alluvial
1.87	2.58	2.65	2.75	3.37	3.88	4.08

subsoil

Source	df	SS	MS	F
Soil Categories	6	16.2597	2.7100	10.09+
Error	37	9.9369	0.2686	
Total	43	26.1966		

Red	Black	Light chestnut	Dark chestnut	Grey	White rendzina	Recent alluvial
1.86	2.47	2.58	2.80	2.92	3.60	3.72

+ Significant at the 5% level.

++ Soil categories which do not differ significantly have been underlined.

were lowest in nitrogen content, as expected, because they were low in organic matter. The recent alluvial soils were highest in nitrogen content and differed significantly from all soil categories. The grey soils were significantly higher than the dark chestnut, black and white rendzina soils while the light chestnut soils were intermediate, but they did not differ statistically from the white rendzina soils. The same trend of grouping was observed in the subsoil.

The carbon-nitrogen ratio ranged from 13.1:1 to 18.1:1 for the surface soil and from 13.0:1 to 18.2:1 for the subsoil, as indicated in Table V. Usually in most arable soils in which organic materials are well decomposed, the carbon-nitrogen ratio is around 10. However, the carbon compounds present in the tested soils were very heterogenous, and in varying stages of decomposition of manure. It was observed that in almost all soil categories the organic matter was not totally decomposed.

Available phosphorus was determined by two methods, Olsen's and Bray and Kurtz No.1. High correlation, $r = 0.94$, and no significant difference between the two methods was observed. The amount for the surface soil ranged from 7.27 to 53.12 pp2m of P_2O_5 as determined by the Olsen method and 7.10 to 57.44 pp2m of P_2O_5 as determined by the Bray and Kurtz No.1. While for the subsoil, it ranged from 6.70 to 52.77 pp2m of P_2O_5 as determined by

Table X. Analysis of variance and mean values of the surface and subsoil for total nitrogen expressed in percentage.[++]

surface soil

Source	df	SS	MS	F
Soil Categories	6	0.0305	0.0051	102.00[+]
Error	37	0.0017	0.00005	
Total	43	0.0322		

Red	Dark chestnut	Black	White rendzina	Light chestnut	Grey	Recent alluvial
0.087	0.127	0.127	0.132	0.139	0.152	0.178

subsoil

Source	df	SS	MS	F
Soil Categories	6	0.0283	0.0047	94.00[+]
Error	37	0.0019	0.00005	
Total	43	0.0302		

Red	Black	Dark chestnut	White rendzina	Light chestnut	Grey	Recent alluvial
0.079	0.117	0.119	0.123	0.130	0.140	0.169

\+ Significant at the 5% level.
\++ Soil categories which do not differ significantly have been underlined.

the Bray and Kurtz No.1 method. The amount of available phosphorus was expected to be less in the lower horizon, but due to deep plowing, the top and subsoil were mixed and had only slightly less available phosphorus. As shown in Table XI, statistical significance was observed between the soil categories for the Olsen's method. In the case of the surface soil, the white rendzina soils were significantly higher in available phosphorus than the light chestnut, black, recent alluvial and red soils, while the dark chestnut and grey soils were intermediate. Thetrend of values for available phosphorus, was about the same in the subsoils as in the surface soils. The differences in amounts in the various soil categories, were probably due to the different rates of application of phosphorus fertilizers and manure.

The cation exchange capacity was found to be high for all soil mapping units, because the clay content was relatively high. It ranged from 39.6 to 53.3 m.e./100 gm. of soil for the surface soil and 39.2 to 51.9 m.e./100 gm. of soil for the subsoils. In general, the cation exchange capacity of the subsoil was lower than the surface soil, as the clay fraction and the organic matter contents were less in the subsoil. However, the decrease was not statistically significant, due to the mixing of the top and subsoils by deep plowing. As shown in Table XII, the dark chestnut, light chestnut and black soils were significantly

Table XI. Analysis of variance and mean values of the surface and subsoil for available phosphorus expressed in parts per two millions.++

surface soil

Source	df	SS	MS	F
Soil Categories	6	5.5445	0.9240	21.00+
Error	37	1.6265	0.0440	
Total	43	7.1710		

Light chestnut	Black	Recent alluvial	Red	Dark chestnut	Grey	White rendzina
7.27	9.84	9.88	10.96	23.87	24.96	53.12

subsoil

Source	df	SS	MS	F
Soil Categories	6	5.4412	0.9068	24.31+
Error	37	1.3801	0.0373	
Total	43	6.8213		

Light chestnut	Red	Black	Recent alluvial	Dark chestnut	Grey	White rendzina
6.70	8.42	8.90	11.33	20.07	23.83	52.77

+ Significant at the 5% level.
++ Soil categories which do not differ significantly have been underlined.

higher in cation exchange capacity than the grey, recent alluvial, red and white rendzina soils, but the grey soils did not differ statistically from the black soils. In the case of the subsoil, the light and dark chestnut were significantly higher than the black, grey, recent alluvial, red and white rendzina soils, but the black soils did not differ statistically from the dark chestnut soils. In general, relatively high amounts of organic matter increase the cation exchange capacity of soils. In the case of the tested soils, apparently differences in organic matter contents among the soil categories, were not great enough to affect the cation exchange capacity very much. On the other hand, the clay content greatly affected the cation exchange capacity as a correlation of $r = 0.92$ was calculated.

The exchangeable sodium content ranged from 0.29 to 0.40 m.e./100 gm. of soil for the surface soil and 0.26 to 0.38 m.e./100 gm. of soil for the subsoil. No statistical significance was observed between any soil category, as shown in Table XIII, for both surface and subsoils.

The exchangeable potassium ranged from 0.70 to 1.36 m.e./100 gm. of soil for the surface soil and 0.68 to 1.30 m.e./100 gm. of soil for the subsoil. The subsoil had slightly lower amounts, as was the case for cation exchange capacity and exchangeable sodium. As shown in

Table XII. Analysis of variance and mean values of the surface and subsoil for cation exchange capacity expressed in milliequivalent per hundred grams of soil.++

surface soil

Source	df	SS	MS	F
Soil Categories	6	1164.58	194.10	4.54+
Error	37	1579.99	42.70	
Total	43	2744.57		

White rendzina	Red	Recent alluvial	Grey	Black	Light chestnut	Dark chestnut
39.6	41.5	42.6	43.0	46.4	52.9	53.3

subsoil

Source	df	SS	MS	F
Soil Categories	6	907.23	151.20	4.03+
Error	37	1388.04	37.51	
Total	43	2295.27		

White rendzina	Red	Recent alluvial	Grey	Black	Dark chestnut	Light chestnut
39.2	40.8	41.8	42.9	45.1	50.3	51.9

+ Significant at the 5% level.
++ Soil categories which do not differ significantly have been underlined.

Table XIII. Analysis of variance and mean values of the surface and subsoil for exchangeable sodium expressed in milliequivalent per hundred grams of soil.++

surface soil

Source	df	SS	MS	F
Soil Categories	6	0.0666	0.0111	0.99
Error	37	0.4128	0.0112	
Total	43	0.4794		

Grey	Black	Dark chestnut	Light chestnut	Recent alluvial	White rendzina	Red
0.29	0.30	0.30	0.30	0.33	0.36	0.40

Subsoil

Source	df	SS	MS	F
Soil Categories	6	0.0854	0.0142	1.45
Error	37	0.3647	0.0098	
Total	43	0.4501		

Grey	Black	Light chestnut	Dark chestnut	Recent alluvial	White rendzina	Red
0.26	0.27	0.27	0.28	0.32	0.34	0.38

+ Significant at the 5% level.
++ Soil categories which do not differ significantly have been underlined.

Table XIV, the light chestnut soils were significantly higher in exchangeable potassium than the rest of the soil categories for both surface and subsoils.

The percentages of silica, alumina and iron oxides were determined on the clay fraction less than 0.2 microns. From each soil category, three soil samples were chosen at random mixed together and taken as a representative of the soil category. The results are shown in Table XV. The silica sesqui-oxide ratio ranged from 2.18 to 2.68. The critical ratio is recognized as 2 (62). Soils with higher ratios are generally plastic and erosive, and those of lower ratios are friable and less erosive. Clays of 2:1 type, have high silica to sesqui-oxide ratio compared to 1:1 type of clays. From the results, it is likely that the less than 0.2 microns clays of Beka'a are 2:1 type of clays.

A key to the diagrammatic presentation of the physical and chemical properties of the surface soil is shown in Figure III. Figure IV shows the diagrammatic presentation of the physical and chemical properties of the surface soil of the seven categories.

The results of individual samples of surface and subsoils for the physical and chemical analysis are found in Appendix Tables XVI to XIX.

From the above discussion, it would be observed that there were differences among the soil categories for

Table XIV. Analysis of variance and mean values of the surface and subsoil for exchangeable potassium expressed in milliequivalent per hundred grams of soil.++

surface soil

Source	df	SS	MS	F
Soil Categories	6	2.0503	0.3417	6.24+
Error	37	2.0267	0.0548	
Total	43	4.0770		

Dark chestnut	Red	Recent alluvial	White rendzina	Black	Grey	Light chestnut
0.70	0.74	0.75	0.84	0.87	0.88	1.36

subsoil

Source	df	SS	MS	F
Soil Categories	6	1.8750	0.3125	5.94+
Error	37	1.9466	0.0526	
Total	43	3.8216		

Dark chestnut	Red	Recent alluvial	White rendzina	Black	Grey	Light chestnut
0.68	0.71	0.72	0.80	0.82	0.85	1.30

\+ Significant at the 5% level.
++ Soil categories which do not differ significantly have been underlined.

Table XV. Percentages of silica, alumina and iron oxides of the clay fraction less than 0.2 microns of the surface soil from the central Beka'a area.

Soil Category	Silica oxide percent	Aluminium oxide percent	Iron oxide percent	Silica sesqui-oxide ratio
Red soils (terra rosa)	40.62	22.20	14.72	2.18
Recent alluvial soils	40.73	16.84	11.32	2.86
White rendzina soils	42.59	20.44	12.84	2.52
Light chestnut soils	41.66	19.64	10.70	2.62
Dark chestnut soils	38.70	22.42	10.20	2.26
Grey soils	39.63	21.67	11.16	2.33
Black soils	40.05	20.52	10.82	2.46

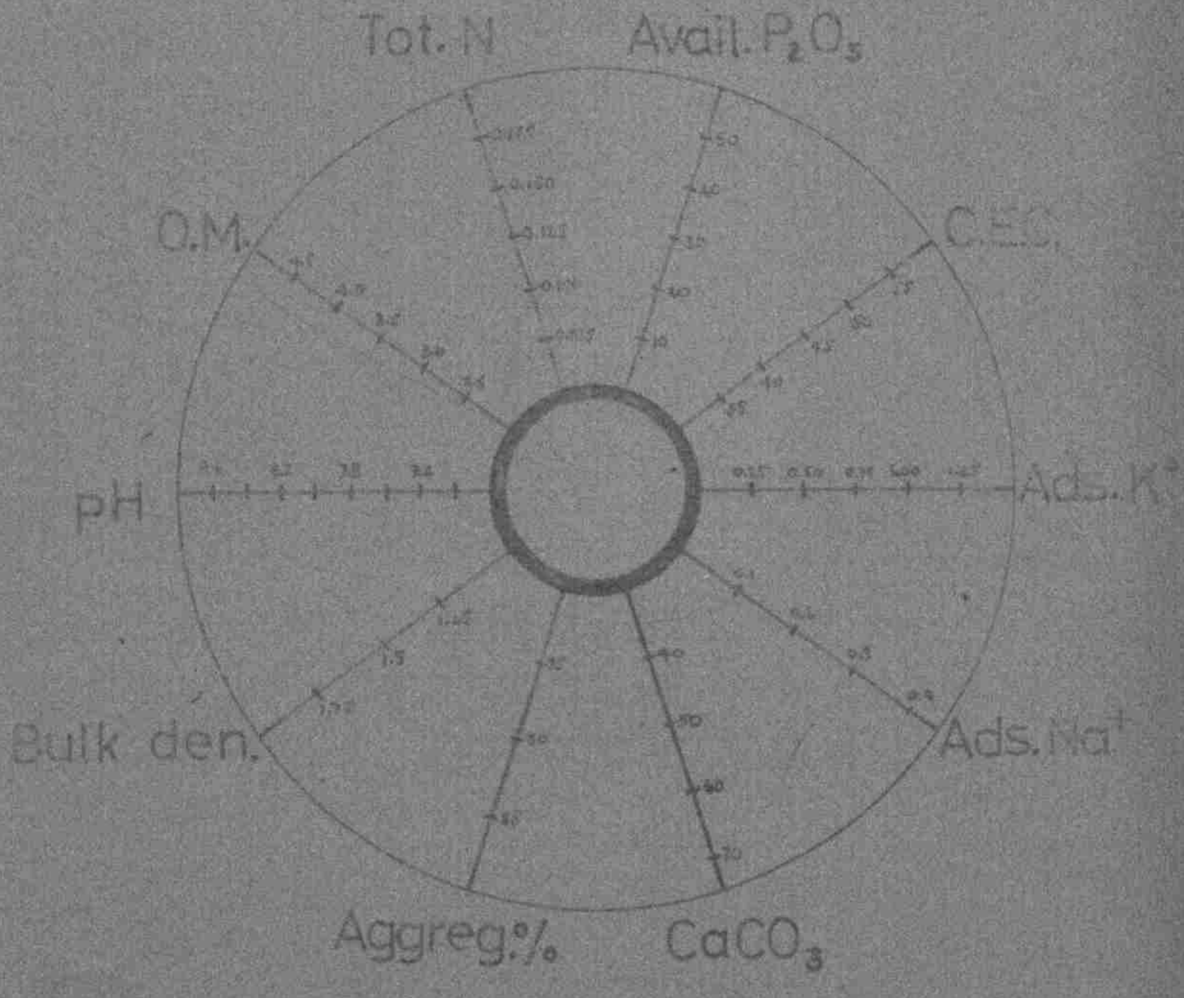


Figure III. Key to the diagrammatic presentation of the physical and chemical properties of the surface soil.

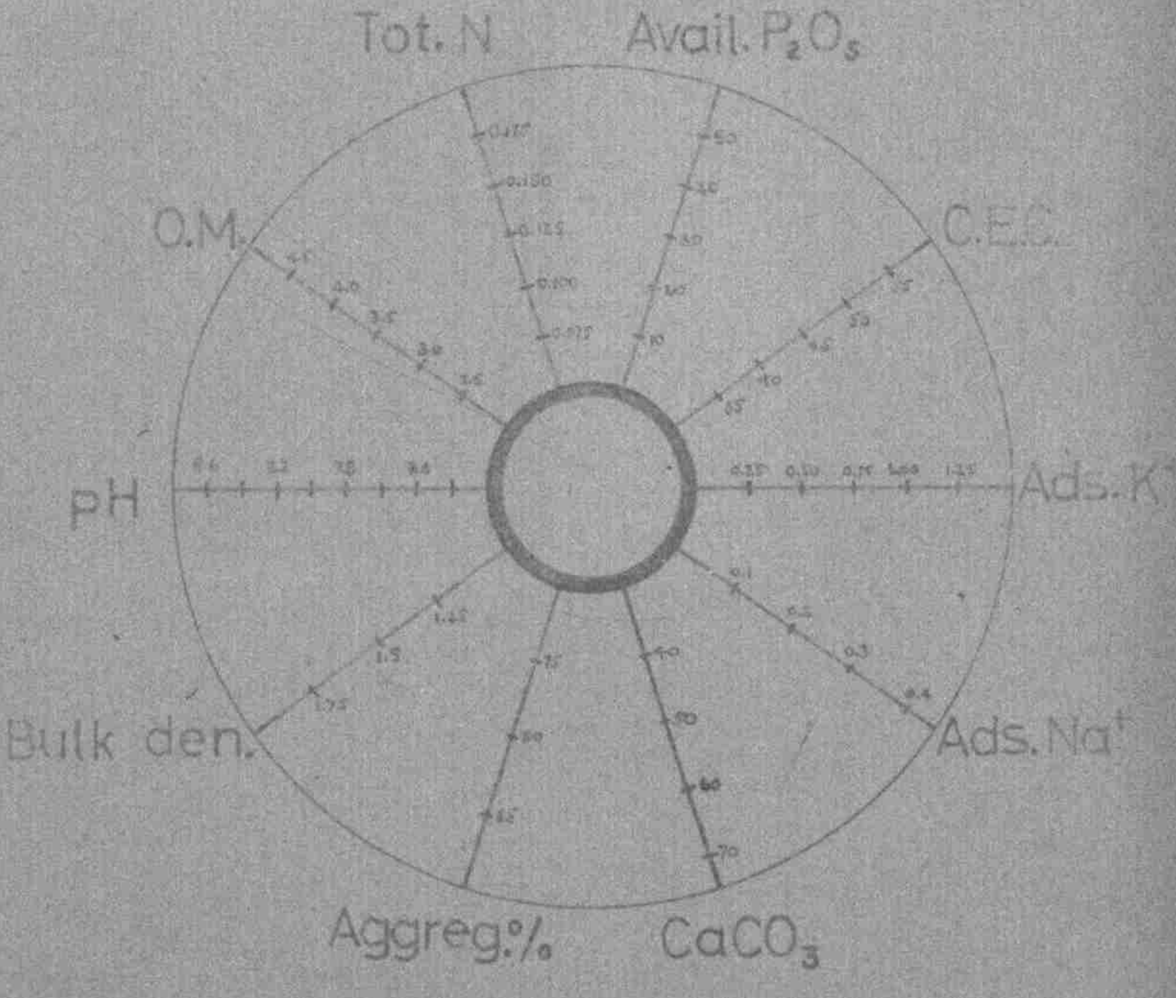


Figure III. Key to the diagrammatic presentation of the physical and chemical properties of the surface soil.

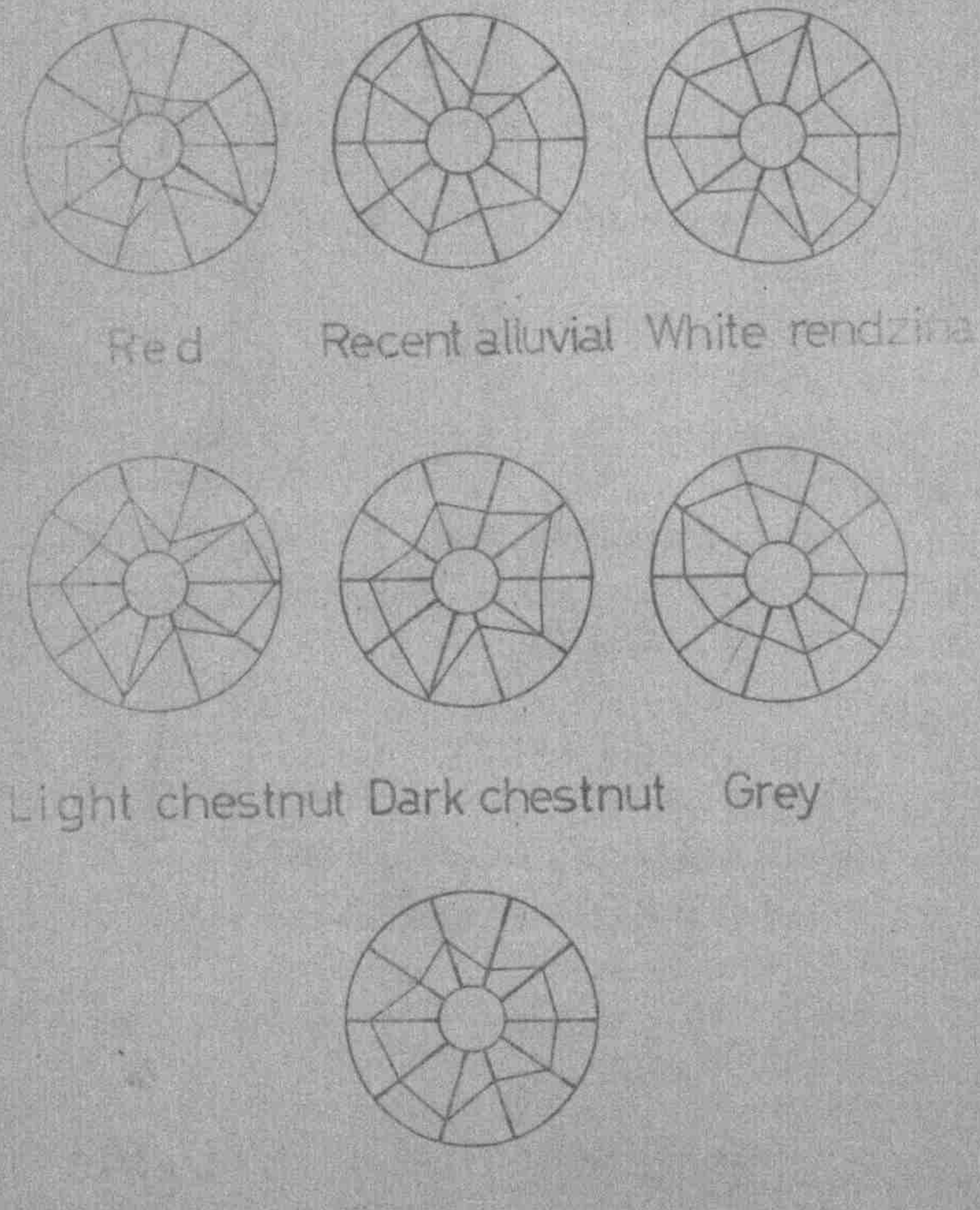


Figure IV. Diagrammatic presentation of the physical and chemical properties of the surface soil in the seven categories (one-third scale of Fig.III).

some of the physical and chemical properties determined.

The red soils were significantly lower than the rest of the soil categories in organic matter, total nitrogen and calcium carbonate contents. It could be observed that the red soils were also low in pH and cation exchange capacity.

The recent alluvial soils were significantly higher than the rest of the soil categories in total nitrogen content. These soils were high in organic matter content. It could be noted that the recent alluvial soils were intermediate in calcium carbonate contents, pH, cation exchange capacity and percentage aggregation. The reason might be that these soils were transported, and were a mixture of various soil forming materials.

The white rendzina soils were significantly higher in available phosphorus and calcium carbonate contents than the rest of the soil categories. The high amounts of calcium carbonate were suggested by the greyish white color of the soil. It could be observed that the white rendzina soils were the lowest in cation exchange capacity and percentage aggregation, which were directly related to the low clay content.

The light chestnut soils were significantly higher in exchangeable potassium than the rest of the soil categories. Statistical difference was observed between the light and dark chestnut soils in total nitrogen and available phosphorus contents; but in the case of organic matter, cation exchange capacity, calcium carbonate and pH, no significant differences were observed between the two categories. The dark chestnut soils differed significantly from the grey soils in all physical and chemical properties determined, while it only differed significantly from the black soils in available phophorus content.

The black soils were low in organic matter content, which suggested that their color is not due to humus but to other minerals or pigments. The black and grey soils were significantly different in all the physical and chemical properties determined, except in cation exchange capacity and bulk density, even though they were classified as one category in the soil map by Geze (23). Thus, it is indicated that the black and grey soils should be placed in separate categories.

In general it was concluded that Geze was justified in placing the Beka'a soils into the categories used and that his division based chiefly on color differences were related to differences in laboratory determinations of certain chemical and physical properties.

SUMMARY AND CONCLUSIONS

A study was made on some soils of the central Beka'a to determine some of their physical and chemical properties and their relationship to soil classification. Determination of some of the available nutrients of the soils in relation to soil mapping units was included.

Samples from forty four locations representing seven soil mapping units according to Geze (23), were collected. Based to a considerable extent on soil color, the soil mapping categories studied were the red, recent alluvial, white rendzina, light chestnut, dark chestnut, grey and black soils.

All soils were fine in texture with an average bulk density of 1.6 gm./c.c. The clay fraction less than 0.2 microns ranged from 11.4 to 24.2 percent of the total clay fraction of the soil. The aggregation percentage ranged between 74.6 and 89.2 percent. The soil reaction of all soils was alkaline, pH 8.0-8.3, with a high content of calcium carbonate, 34.7 to 71.1 percent. The content of organic matter ranged from 2.03 to 4.62 percent, total nitrogen content ranged from 0.08 to 0.18 percent and available phosphorus ranged from 6.70 to 53.12 pp2m. The cation exchange capacity ranged from 39.2 to 53.3 m.e./100 gm. of soil. The exchangeable sodium ranged from 0.26 to 0.40 m.e./100 gm. of soil, while the exchangeable potassium ranged from 0.68 to 1.36 m.e./100 gm. of soil, an amount considered adequate for crop growth. The silica sesqui-oxide ratio of the clay fraction less than 0.2 microns, ranged from 2.18 to 2.68.

Differences among soil categories with respect to their physical and chemical properties were observed as follows:

Organic matter, total nitrogen and calcium carbonate contents were lower in the red soils than in the other soil categories. Red soils in general were found to be low in pH and cation exchange capacity.

The recent alluvial soils were significantly higher than other soil categories in total nitrogen and organic matter contents, but were intermediate in pH, percentage aggregation, cation exchange capacity and calcium carbonate content.

The white rendzina soils were significantly higher than other soil categories in available phosphorus and calcium carbonate contents, while they ranged lowest in cation exchange capacity and percentage aggregation.

Exchangeable potassium was highest in the light chestnut soils. No significant difference was observed between light and dark chestnut soils with respect to organic matter, cation exchange capacity, calcium carbonate content and pH, while the light chestnut soils were significantly higher than the dark chestnut soils in total nitrogen and available phosphorus contents.

The dark chestnut soils differed significantly from the grey soils in all physical and chemical properties determined except in available phosphorus, pH, exchangeable sodium and potassium and bulk density.

The black and grey soils should be separately mapped, as significant differences were observed between them. The grey soils were significantly higher in organic matter, total nitrogen and available phosphorus contents than the black soils, while the latter were significantly higher in pH and aggregation percentage than the grey soils.

No statistically significant differences were observed between the surface and subsoils with respect to their physical and chemical properties.

The classification of the Beka'a soils into categories based chiefly on soil color by Geze concurred with the findings of this study, based on physical and chemical properties of these soils.

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APPENDIX

Table XVI. Physical analysis of the surface soil from the central Beka'a from 44 individual soil sampling sites.

Soil Category	Sample No.	Color+	Sand percent	Silt percent	Clay percent	Clay fraction less than 0.2μ percent of clay	Clay fraction less than 0.2μ percent of soil	Aggregate++ percent	Bulk density gm./ c.c.	Moisture content percent
Red Soils (terra rosa)	8	2.5YR 4/6	16.97	17.73	65.30			82.94	1.98	8.11
	20	2.5YR 4/8	12.93	25.21	61.86	16.6	10.3	75.52	1.44	8.23
	23	10R 4/4	18.55	21.11	60.44			85.63	1.79	6.55
	24	2.5YR 4/4	31.65	16.53	51.82			79.28	2.27	6.55
	25	10R 4/4	37.58	11.30	51.12	14.9	7.6	81.36	1.56	5.15
	26	10R 4/6	34.74	14.71	50.55	13.5	6.8	78.91	1.56	6.25
	31	5YR 4/4	11.00	18.26	70.74			83.22	1.62	9.53
Recent Alluvial soils	1	10YR 5/4	18.15	28.24	53.61	13.9	7.4	84.88	1.61	6.84
	2	10YR 5/4	17.09	29.49	53.42			84.47	1.57	6.39
	18	10YR 6/3	17.92	22.59	59.49	14.3	8.5	83.83	1.44	5.10
	37	10YR 5/4	21.38	19.92	58.70			81.62	1.57	7.06
	46	10YR 6/3	15.60	24.68	59.72	15.4	9.2	84.40	1.63	5.54
	47	10YR 6/3	18.42	26.48	55.10			85.50	1.59	6.78
White Rendzina soils	21	10YR 8/3	18.96	30.13	50.91	10.9	5.5	69.35	1.50	3.90
	22	10YR 8/3	8.68	29.55	61.77	11.6	7.2	74.50	1.50	3.95
	34	2.5Y 7/2	15.90	31.83	52.27			67.91	1.58	3.30
	35	2.5Y 7/2	15.32	32.44	52.19			76.53	1.98	4.75
	36	10YR 7/3	16.55	28.64	54.81	11.6	6.4	76.75	1.75	3.79
	41	7.5YR 6/4	19.02	26.07	54.91			82.28	1.40	5.75
Light Chestnut soils	3	10YR 5/4	7.22	30.21	62.57			91.93	1.78	6.38
	4	10YR 5/4	4.95	22.45	72.60	24.3	17.6	91.16	1.52	9.05
	7	7.5YR 4/4	13.66	24.88	61.46			90.37	1.77	8.26
	16	7.5YR 4/4	11.34	23.46	62.50			88.16	1.70	7.64
	17	10YR 5/4	14.52	24.86	60.62	22.6	13.7	80.40	1.64	7.07
	19	10YR 5/4	13.51	25.30	61.19	25.7	15.7	76.12	1.53	8.11
	42	7.5YR 4/4	11.73	19.27	69.00			94.72	0.92	3.57

+ determined on the dry soil samples.

++ Aggregation of particles less than 50 microns expressed in percentage.

Table XVI. continued. Physical analysis of the surface soil from the central Beka'a from 44 individual soil sampling sites.

Soil Category	Sample No.	Color +	Sand percent	Silt percent	Clay percent	Clay fraction less than 0.2μ percent of clay	Clay fraction less than 0.2μ percent of soil	Aggregate ++ percent	Bulk density gm./ c.c.	Moisture content percent
Dark Chestnut soils	5	10YR 4/3	19.33	18.42	62.25			90.41	1.60	9.30
	6	10YR 4/3	17.58	15.96	66.46	17.6	11.7	92.62	1.44	9.29
	9	10YR 5/4	7.68	25.73	66.59	18.6	12.4	85.48	1.77	8.11
	10	10YR 5/4	6.56	26.14	67.30			89.37	1.44	8.93
	11	10YR 5/4	9.07	18.67	72.26	19.7	14.2	89.92	1.74	8.47
	40	10YR 4/3	15.87	17.78	66.35			87.64	1.68	8.35
Grey soils	12	7.5YR 5/2	19.86	32.12	48.02	15.0	7.2	67.16	1.42	2.62
	13	7.5YR 4/2	10.78	35.52	53.70			72.65	1.38	5.71
	15	10YR 3/2	4.78	31.23	63.99			81.78	1.43	9.71
	27	10YR 4/2	4.72	32.05	63.23	14.8	9.3	83.86	1.49	7.87
	29	10YR 4/2	13.15	30.40	56.45			72.28	1.31	3.41
	30	10YR 4/2	9.60	23.31	67.09	12.9	8.3	81.72	1.61	8.92
Black soils	28	10YR 4/1	8.09	28.43	63.48	22.7	14.4	88.32	2.08	10.10
	32	10YR 5/2	17.42	24.45	58.13			73.89	1.46	2.74
	33	10YR 3/2	9.45	29.91	60.64			87.68	1.71	11.50
	43	10YR 3/3	5.60	22.25	72.15	24.0	17.3	88.33	1.40	9.80
	44	10YR 4/2	7.76	31.54	60.70			88.76	1.59	10.30
	45	10YR 5/2	6.08	23.42	70.50	21.8	15.4	86.56	1.57	11.42

\+ determined on the dry soil samples.

++ Aggregation of particles less than 50 microns expressed in percentage.

Table XVII. Physical analysis of the subsoil from the central Beka'a from 44 individual soil sampling sites.

Soil Category	Sample No.	Color+	Sand percent	Silt percent	Clay percent	Moisture content percent.
Red soils (terra rosa)	8	2.5YR 4/6	15.34	17.24	67.42	9.09
	20	2.5YR 4/8	13.80	21.44	64.76	8.23
	23	10R 4/4	24.03	31.25	44.72	6.95
	24	2.5YR 4/4	24.88	26.25	48.87	6.73
	25	10R 4/4	37.30	21.88	40.82	5.15
	26	10R 4/6	37.13	20.60	42.27	6.20
	31	5YR 4/4	31.39	18.41	50.20	9.62
Recent Alluvial soils	1	10YR 5/4	19.05	28.84	52.11	6.84
	2	10YR 5/4	24.31	26.86	48.83	6.38
	18	10YR 6/3	17.44	27.06	55.50	5.25
	37	10YR 5/4	9.60	30.63	59.77	7.01
	46	10YR 6/3	18.13	27.22	54.65	5.54
	47	10YR 6/3	8.05	27.13	64.82	6.84
White Rendzina soils	21	10YR 8/3	20.82	33.67	45.51	3.90
	22	10YR 8/3	12.72	34.61	52.63	3.62
	34	2.5Y 7/2	10.11	34.37	55.52	3.20
	35	2.5Y 7/2	16.11	27.61	56.28	4.60
	36	10YR 7/3	12.60	29.48	57.92	3.79
	41	7.5YR 6/4	19.23	30.10	50.67	5.75
Light Chestnut soils	3	10YR 5/4	9.45	26.92	63.63	6.38
	4	10YR 5/4	5.06	25.40	69.54	9.05
	7	7.5YR 4/4	17.55	20.99	61.46	8.22
	16	7.5YR 4/4	13.71	27.33	58.96	7.64
	17	10YR 5/4	21.77	22.79	55.44	7.01
	19	10YR 5/4	13.30	31.78	54.92	8.11
	42	7.5YR 4/4	13.99	19.98	66.03	3.52

+determined on the dry soil samples.

Table XVII. continued. Physical analysis of the subsoil from the central Beka'a from 44 individual soil sampling sites.

Soil Category	Sample No.	Color+	Sand percent	Silt percent	Clay percent	Moisture content percent
Dark Chestnut soils	5	10YR 4/3	17.69	17.60	64.41	9.30
	6	10YR 4/3	18.89	24.49	56.62	9.29
	9	10YR 5/4	8.00	28.43	63.57	8.05
	10	10YR 5/4	10.58	28.72	60.70	8.81
	11	10YR 5/4	6.54	21.04	72.42	8.35
	40	10YR 4/3	8.82	27.50	63.68	8.29
Grey soils	12	7.5YR 7/2	12.68	36.22	51.10	2.56
	13	7.5YR 4/2	6.77	35.30	57.93	5.66
	15	10YR 3/2	7.08	30.90	62.02	9.17
	27	10YR 4/2	4.92	36.00	59.08	7.82
	29	10YR 4/2	16.15	36.50	47.35	3.41
	30	10YR 4/2	5.24	28.62	66.14	8.81
Black soils	28	10YR 4/1	7.04	25.84	67.12	10.10
	32	10YR 5/2	10.54	28.04	61.42	2.70
	33	10YR 3/2	11.10	30.32	58.58	11.50
	43	10YR 3/3	8.08	24.09	67.83	9.80
	44	10YR 4/2	7.63	35.79	56.58	10.30
	45	10YR 5/2	5.18	30.86	63.96	11.42

+ determined on the dry soil samples.

Table XVIII. Chemical analysis of the surface soil from the central Beka'a from 44 individual soil sampling sites.

Soil Category	Sample No.	pH 1:2.5	Organic Matter dry combustion percent	Organic Matter wet combustion percent	Total Nitrogen percent	Available Phosphorus pp2m Olsen's Method	Available Phosphorus pp2m Bray & Kurtz No.1 Method	Cation Exchange Capacity m.e./100 gm. of soil	Adsorbed Cations m.e./100 gm. of soil Na	Adsorbed Cations m.e./100 gm. of soil K	Calcium Carbonate percent
Red soils (terra rosa)	8	7.9	1.85	1.67	0.086	4.35	4.25	56.1	0.63	0.92	28.9
	20	8.1	2.09	1.86	0.094	4.35	4.31	50.2	0.47	0.76	33.1
	23	8.1	1.66	1.51	0.080	3.82	4.24	35.4	0.31	0.84	45.2
	24	8.1	1.77	1.49	0.082	19.36	19.41	31.9	0.25	0.43	30.1
	25	7.8	2.23	2.04	0.094	5.05	4.98	29.7	0.33	0.64	34.0
	26	8.1	2.37	2.24	0.082	19.57	18.54	31.5	0.38	0.75	33.8
	31	8.0	2.61	2.26	0.090	20.23	19.50	52.6	0.43	0.87	37.8
Recent Alluvial soils	1	8.2	4.50	3.88	0.181	6.38	6.93	41.8	0.33	0.81	44.2
	2	8.2	3.81	3.60	0.193	12.77	12.30	38.7	0.27	0.59	45.0
	18	8.3	4.30	4.14	0.174	16.84	15.24	45.8	0.28	0.49	56.7
	37	8.2	3.96	3.88	0.164	10.75	9.40	39.6	0.39	0.92	54.5
	46	8.2	4.72	4.44	0.176	6.32	6.60	47.9	0.43	0.96	53.0
	47	8.2	4.85	4.56	0.182	6.24	5.78	41.8	0.32	0.74	46.1
White Rendzina soils	21	8.4	5.49	4.12	0.136	58.95	55.68	40.2	0.58	1.07	72.0
	22	8.4	3.52	3.48	0.123	71.86	69.98	44.4	0.31	0.79	71.4
	34	8.3	4.32	4.16	0.140	46.19	47.27	39.7	0.41	0.67	70.5
	35	8.2	4.10	3.62	0.132	40.62	37.93	36.6	0.23	0.95	71.6
	36	8.3	5.02	4.42	0.127	66.66	65.32	35.9	0.36	0.71	70.9
	41	8.3	3.09	3.48	0.133	34.82	32.46	40.6	0.28	0.86	62.7
Light Chestnut soils	3	8.4	3.86	3.46	0.145	4.90	4.16	52.2	0.32	1.26	44.7
	4	8.3	3.26	2.82	0.134	5.87	5.04	58.2	0.26	1.64	34.2
	7	7.9	3.18	2.75	0.148	4.35	4.69	57.8	0.41	0.88	33.2
	16	8.2	2.85	2.43	0.138	8.60	7.74	53.0	0.13	1.93	26.3
	17	8.2	3.01	2.62	0.130	15.05	15.78	48.3	0.19	1.71	33.3
	19	8.3	1.69	1.34	0.137	5.87	6.30	45.3	0.28	1.37	35.9
	42	8.3	4.40	3.84	0.142	6.25	6.01	55.7	0.48	0.75	57.9

Table XVIII. continued. Chemical analysis of the surface soil from the central Beka'a from 44 individual soil sampling sites.

Soil Category	Sample No.	pH 1:2.5	Organic Matter dry combustion percent	Organic Matter wet combustion percent	Total Nitrogen percent	Available Phosphorus pp2m Olsen's Method	Available Phosphorus pp2m Bray & Kurtz No.1 Method	Cation Exchange Capacity m.e./100 gm. of soil	Adsorbed Cations m.e./100 gm. of soil Na	Adsorbed Cations m.e./100 gm. of soil K	Calcium Carbonate percent
Dark Chestnut soils	5	8.3	4.28	3.81	0.126	27.92	25.20	56.2	0.21	0.74	36.4
	6	8.0	2.92	2.62	0.133	38.46	38.06	53.8	0.30	0.66	34.8
	9	8.2	2.40	2.30	0.133	15.22	14.40	49.6	0.34	0.57	38.1
	10	8.3	2.51	2.17	0.120	6.52	6.95	51.7	0.39	0.75	40.3
	11	8.3	3.09	2.86	0.121	34.34	30.66	58.6	0.21	0.85	41.6
	40	8.0	2.40	2.16	0.128	20.22	17.68	49.7	0.37	0.66	26.6
Grey soils	12	8.1	3.63	3.36	0.153	25.98	27.32	38.9	0.16	0.81	70.7
	13	8.0	3.86	3.45	0.142	26.39	26.52	36.5	0.23	0.96	65.1
	15	8.1	3.65	3.36	0.151	42.00	41.00	47.3	0.30	0.67	43.0
	27	8.2	4.63	4.16	0.152	20.00	20.23	43.7	0.36	0.80	45.2
	29	8.1	3.28	3.08	0.155	15.67	15.00	35.4	0.28	1.08	56.9
	30	8.0	3.26	2.79	0.150	19.78	18.80	55.1	0.42	0.98	44.1
Black soils	28	8.3	3.16	2.79	0.131	15.39	14.86	41.7	0.45	0.89	37.6
	32	8.2	2.30	2.10	0.134	12.99	12.60	42.9	0.18	0.76	70.1
	33	8.3	3.01	2.52	0.127	8.25	7.66	37.7	0.29	1.32	36.1
	43	8.2	3.09	2.79	0.118	6.45	6.74	56.2	0.36	0.73	46.2
	44	8.3	2.44	2.41	0.128	9.46	9.78	48.4	0.21	0.67	44.1
	45	8.3	3.18	2.90	0.132	6.51	6.89	51.4	0.29	0.83	40.1

Table XIX. Chemical analysis of the subsoil from the central Beka'a from 44 individual soil sampling sites.

Soil Category	Sample No.	pH 1:2.5	Organic Matter dry combustion percent	Organic Matter wet combustion percent	Total Nitrogen percent	Available Phosphorus pp2m Olsen's Method	Available Phosphorus pp2m Bray & Kurtz No. 1 Method	ation Exchange Capacity m.e./100 gm. of soil	Adsorbed Cations m.e./100 gm. of soil Na	Adsorbed Cations m.e./100 gm. of soil K	Calcium Carbonate percent
Red soils (terra rosa)	8	7.9	1.96	1.74	0.079	3.48	3.21	55.4	0.59	0.88	31.3
	20	8.2	1.89	1.76	0.087	5.22	5.14	48.2	0.45	0.70	33.0
	23	8.0	1.56	1.56	0.075	4.26	4.30	36.6	0.33	0.82	45.8
	24	8.0	1.72	1.96	0.072	13.85	13.65	32.6	0.27	0.40	32.0
	25	7.9	2.23	1.93	0.085	4.21	4.14	28.7	0.29	0.60	34.2
	26	8.0	2.30	2.16	0.074	12.63	11.95	32.3	0.36	0.72	35.4
	31	8.0	2.54	2.31	0.084	15.22	14.75	51.9	0.40	0.86	39.5
Recent Alluvial soils	1	8.3	4.16	3.79	0.172	5.11	4.94	40.8	0.36	0.79	44.2
	2	8.2	3.37	3.38	0.179	14.90	13.64	36.2	0.18	0.55	45.5
	18	8.3	3.64	4.09	0.162	18.94	17.86	45.9	0.27	0.46	56.4
	37	8.2	3.40	3.42	0.156	13.56	11.70	38.0	0.37	0.90	54.7
	46	8.3	3.78	3.50	0.172	6.32	6.28	46.2	0.43	0.92	53.8
	47	8.2	4.36	4.16	0.174	8.60	7.90	43.6	0.32	0.72	46.1
White Rendzina soils	21	8.4	4.54	4.32	0.127	66.66	58.20	37.3	0.56	1.03	72.3
	22	8.4	4.05	3.02	0.116	67.08	66.52	43.7	0.31	0.75	72.1
	34	8.3	4.24	3.50	0.128	42.12	40.94	39.8	0.37	0.62	73.2
	35	8.2	3.98	3.58	0.120	44.99	43.21	37.2	0.20	0.90	72.8
	36	8.3	4.39	4.16	0.122	61.60	60.25	36.2	0.36	0.70	73.9
	41	8.3	3.28	3.05	0.124	33.70	31.90	41.2	0.26	0.83	62.4
Light Chestnut soils	3	8.4	3.30	2.98	0.136	4.26	4.30	48.7	0.31	1.20	45.2
	4	8.3	3.22	2.84	0.126	4.78	4.96	56.8	0.23	1.57	34.8
	7	8.0	2.58	2.36	0.132	3.91	4.25	58.5	0.37	0.83	34.2
	16	8.2	2.46	2.16	0.131	10.75	8.20	53.0	0.14	1.85	27.1
	17	8.3	2.58	2.24	0.120	12.90	13.86	47.6	0.16	1.68	33.8
	19	8.2	1.58	1.55	0.132	5.85	5.80	44.5	0.24	1.28	36.8
	42	8.3	4.54	3.90	0.135	4.76	5.30	54.3	0.43	0.72	58.2

Table XIX. continued. Chemical analysis of the subsoil from the central Beka'a from 44 individual soil sampling sites.

Soil Category	Sample No.	pH 1:2.5	Organic Matter dry combustion percent	Organic Matter wet combustion percent	Total Nitrogen percent	Available Phosphorus pp2m Olsen's Method	Available Phosphorus pp2m Bray & Kurtz No. 1 Method	tion Exchange Capacity .e./100 gm. of soil	Adsorbed Cations m.e./100 gm. of soil Na	Adsorbed Cations m.e./100 gm. of soil K	Calcium Carbonate percent
Dark Chestnut soils	5	8.1	3.95	3.64	0.120	20.54	20.00	52.2	0.21	0.71	37.5
	6	8.1	3.16	2.84	0.126	32.97	31.40	47.8	0.28	0.61	34.2
	9	8.2	2.23	2.05	0.120	13.04	12.45	48.2	0.31	0.58	38.7
	10	8.3	3.61	3.24	0.106	6.52	6.40	53.2	0.36	0.71	40.4
	11	8.3	3.54	3.22	0.115	32.18	30.00	52.7	0.18	0.82	41.3
	40	8.0	2.04	1.84	0.126	15.22	19.52	47.5	0.34	0.62	26.2
Grey soils	12	8.2	3.02	2.80	0.141	22.27	23.60	38.4	0.13	0.77	70.7
	13	8.1	3.30	3.19	0.130	22.13	23.00	38.1	0.22	0.74	64.2
	15	8.1	3.08	2.81	0.152	43.16	41.68	48.2	0.27	0.66	43.2
	27	8.2	3.95	3.62	0.142	19.78	19.44	44.5	0.33	0.76	46.2
	29	8.1	2.98	2.69	0.138	14.43	14.00	36.7	0.24	1.03	57.6
	30	8.0	2.89	2.38	0.136	20.87	19.52	51.4	0.38	0.96	44.6
Black soils	28	8.2	3.07	2.66	0.112	14.22	14.06	42.4	0.42	0.86	38.1
	32	8.2	2.22	2.10	0.130	11.96	11.38	40.7	0.16	0.72	72.1
	33	8.3	2.92	2.72	0.116	7.01	7.32	36.9	0.26	1.26	37.2
	43	8.2	2.06	2.41	0.103	6.85	6.20	52.7	0.33	0.71	46.9
	44	8.3	2.27	2.10	0.118	7.74	8.12	47.8	0.19	0.61	44.8
	45	8.2	3.11	2.82	0.124	5.39	6.06	50.4	0.27	0.79	40.3