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ARE SOILS MAPPED UNDER A GIVEN TYPE
NAME BY THE BUREAU OF SOILS
METHOD CLOSELY SIMILAR
TO ONE ANOTHER?

A THESIS SUBMITTED IN PARTIAL SATISFACTION OF
THE REQUIREMENTS FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY
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BY

ROBERT LARIMORE PENDLETON

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FOREWORD

It is due the author, as well as to the undersigned, that a few words be said by way of preparing the reader for what follows in this paper. It will be observed, first, that the manuscript was, for an unusually long time, in the printer's hands. Those who appreciate, as few do today, the great rapidity with which the theories and the methods in soil and plant study change, will readily catch the significance of the foregoing sentence. Much of the work done by Mr. Pendleton and some of the methods used may now properly be considered obsolete, or, conservatively speaking, at least obsolescent. Nevertheless, I deem it of some importance to give the results obtained in more or less detail, because of their historical value, and because Mr.

Pendleton's residence in India since the paper was written by him has rendered satisfactory changes and deletions practically impossible. Under these circumstances, with the burden of preparing the paper for the press and the reading of the proof falling to me, the author cannot well be held responsible for the inaccuracies and the infelicities of expression which have been carried over from the original manuscript without change. Moreover, the investigation was carried out under my direction, and the plan of attack on the problem, together with the methods employed, were suggested by me. Much that, in the light of present knowledge, is superfluous or patently inexact or erroneous in the paper is due to points of view held by me in 1915, but now happily discarded. For all these, I assume the entire responsibility, and absolve Mr. Pendleton in that regard.

On the other hand, the work having been carried out at my suggestion and under my direction, I feel constrained, in justice to myself, to say that the views expressed in this paper, and the conclusions drawn are wholly Mr. Pendleton's and are not in agreement with those held by me. I fail to see the cogency of the arguments set forth for soil classification and mapping at this juncture in soil studies, and cannot admit the pertinence of the analogy between classification of other objects and of soils which the author of this paper employs. My own general conclusion from the results obtained by Mr. Pendleton is that they cast grave doubt on the validity of the Bureau of Soils method of soil classification and mapping, and, incidentally on all methods devised for that purpose to date. I cannot see how such methods can serve us in scientific work at all, and, from the practical standpoint, it would surely seem that guides for the purchaser of land could be arranged more cheaply and less elaborately than by the soil mapping methods extant. This statement has particular reference to the subdivision of types very minutely, such as, for example, sandy silty clay, clay loam adobe, etc. Such minute classification and subdivision in view of the present state of our knowledge of soils, is analogous, in my opinion, to carrying figures out to four decimal places when it is known that the accuracy of the method makes it impossible for them to be correct beyond the first decimal place. In support of this seemingly radical conclusion, the reader will find much of interest in the recent studies of this laboratory on variability in soils, which have already appeared in this same series.

CHAS. B. LIPMAN.

INTRODUCTION

For several years the University of California has been coöperating with the United States Bureau of Soils in the mapping of the soils of the agricultural portions of the State of California. The system of mapping used is that developed by the Bureau of Soils. During the year 1914-1915 the writer, representing the University of California, was engaged in some of this soil survey work. In that year, in the field, many questions arose regarding the criteria used, the methods,

and the results of the scheme of mapping. It was thought that possibly some of the many questions could be answered through a laboratory study of some typical soils. This paper is a description of certain parts of the work done in this connection.

THE NEED OF A CLASSIFICATION OF SOILS

Since soils consist of a number of more or less distinct groups they are fitting subjects for classification. In fact, it is my belief that it is as necessary to have a classification for soils as for any other group of natural objects in order that "the various and complex relations may be shown as far as practicable,"¹ and that there be a definite basis for systematic and thorough investigations.² The advantages of a classification of soils are apparent. But because soils grade gradually into one another, rather than exist as discrete individuals which can be more easily considered and treated from a systematic standpoint, the problem of evolving a satisfactory classification has been particularly difficult. The many and diverse classifications proposed, and the difficulty of applying many of these classifications under conditions other than those for which they were evolved, testify to the difficulty of the task in question.

The mapping of soils without a classification is impossible, and so a brief summary of the development of soil mapping will bear a close relation to the development of soil classification.

HISTORICAL DEVELOPMENT OF THE CLASSIFICATION OF SOILS

The early history of the making of soil maps is that of geologic maps as well, when soils, from the agricultural standpoint, and the less distinct geological formations as such, were not sharply distinguished. Blanck³ has an excellent treatment of the development of soil mapping and of the modern continental European conceptions of the nature and significance of soil maps. According to Blanck the earliest record of a proposal to make a map to show something of the nature of the actual material composing the surface of the earth is that of Lister's proposal, in 1683, to the Royal Society of London.

¹ Coffey, G. N., *Proc. Amer. Soc. Agron.*, vol. 1 (1909), p. 175.

² Cameron, F. K., *Eighth Internat. Cong. Chem.*, vol. 26 (1912), secs. vii-xib; app. pp. 699-706.

³ Fühling, *Landw. Ztg.*, vol. 60 (1911), pp. 121-45.

But it was not until 1743 that Packe executed a map of Kent, showing the occurrence of minerals by symbols. Apparently the next advance was by the Germans, when Füchsel, 1773, and Glöser, 1775, first used colors to show granite, limestone, etc. This work constituted the first real geologic map in the modern sense. There was not much activity in this line of geologic work until 1870 or later. Such activity as there was showed a lack of emphasis on soils in the agricultural sense of the term.

The work on the geologic drifts of northern Europe, and studies of the more recent lowland formations and soils of Germany led to soil mapping. The first real soil map, according to Blanck, was prepared by Benningsten-Förder of Halle, in 1864-67; while Carnot⁴ states that in 1863 M. Scipion Gras used superposable maps of the Department of Isère, showing (1) geology, (2) agricultural soils, (3) altitudes of agricultural regions, and (4) culture. The first true geologic-agronomic map published by the Preussischegeologische Landesanstalt appeared in 1878.

The school of soil classification and mapping just mentioned, using the geologic maps and methods as a point of departure have evolved numerous though similar systems of recording the agrogeologic data on the map. The geologic formation is shown by the color, and the soil textures by symbols, while one or more of the following groups of data appear and may be shown: topography by contours, subterranean water by blue figures, location of borings in red with figures referring to tables, amount of plant food elements or substances by figures or hatchings, varying directions, color, or nature of lines, etc. The nature and amount of the data shown and the manner of representing them vary a great deal. Some soilists, to use a term proposed by Coffey,⁵ advocate and use superposable maps to show one or more groups of data, thus avoiding unnecessary confusion on the main map.

Hazard⁶ proposed a scheme of classification which is quite as directly connected with the economic factors controlling the crops grown, and with the assessable valuation of the land, as with the actual or potential fertility of the soil itself. There are several classifications of this type, involving the assessable values of the land.

⁴ Rapport sur les cartes agronomiques, Bull. Min. Agr. France, 1893, no. 8, pp. 956-73.

⁵ Jour. Amer. Soc. Agron., vol. 8 (1916), p. 239.

⁶ Landw. Jahrb., vol. 29 (1900), pp. 805-911.

Gregoire, A., and Halet, F., Bull. Inst. Chem. et Bact. Gembloux, 1906, no. 75, pp. 1-43.

This development of the mapping of soils as an outgrowth of areal geology in France and Germany may be contrasted with the development of soil classification from other viewpoints, such as that of the Russian school. In Russia there is not the predominance of residual and shallow soils which characterize much of western Europe and which in France especially have led to the adoption of the geologic basis of classification. Dokoutchayev and Sibirtzev have been the chief proponents of a classification of soils based upon the "conception of a soil as a natural body having a definite genesis and a distinct nature of its own."⁷

The genetic conditions of the formation of natural soils include the following variable factors which cause variation:

(1) The petrographic type of the parent rock; (2) the nature and intensity of the processes of disintegration, in connection with the local climatic and topographic conditions; (3) the quantity and quality of that complexity of organisms which participate in the formation of the soil and incorporate their remains in it; (4) the nature of the changes to which these remains are subjected in the soil, under the local climatic conditions and physico-chemical properties of the soil medium; (5) the mechanical displacement of the particles of the soil, provided this displacement does not destroy the fundamental properties of the soil, its geobiological character, and does not remove the soil from the parent rock; and (6) the duration of the processes of soil formation.

Upon this genetic basis there has been developed a series of soil zones, ranging from the laterite soils in the tropics to the tundras in the Arctic regions. The outstanding and controlling factor in the scheme proposed is the relation of these zones to climate. For this reason the statement usually seen is that climate is the basis of the classification.⁸ There are nearly as many groups of intra-zonal and azonal soils as of those belonging to the zones proper. The former include alkali, marshy, alluvial, and other soils.

Hilgard, while actively interested in the genetic viewpoint of soil classification, was the foremost proponent of a classification upon the basis of the natural vegetation growing upon the soil.⁹ This criterion is not always available, though some groups of plants, as the alkali tolerant ones, are almost invariably present where the condi-

⁷ Exp. Sta. Record, vol. 12 (1900), p. 704.

See also Sibirtzev, *Cong. Geol. Intern.*, 1897, pp. 73-125; abstract in *Exp. Sta. Rec.*, vol. 12 (1900-01), pp. 704-12, 807-18.

Tulaikoff, N., *The Genetic Classification of Soils*, *Jour. Agr. Sci.*, vol. 3 (1908), pp. 80-85.

⁸ Coffey, U. S. Bur. Soils, *Bull.* 85 (1912), p. 32; *Jour. Amer. Soc. Agron.*, vol. 8 (1916), p. 241.

⁹ Hilgard, E. W., *Soils* (New York, Macmillan, 1906), pp. 487-549.

tions are unfavorable for the less resistant plants. Later Hilgard and Loughridge¹⁰ claimed that it is impracticable to attempt "a satisfactory tabular classification in which each soil shall at once find its pigeonhole prepared for it . . . because the subject matter is as yet so imperfectly known." However, this does not dispute the justification for making classifications for specific purposes or of specific regions. With respect to this point there seems to be confusion. The question is not whether soils can be classified at all or not, for every observant farmer classifies the soil with which he is familiar, but whether a satisfactory classification is possible over a large territory, where soils are subject to the varying action of the important soil forming agencies.

Still another type of soil mapping is that of Hall and Russell, which is given in their admirable Report on the Agriculture and Soils of Kent, Surrey, and Sussex.¹¹ In this district the soils are largely residual, and form quite distinct groups, depending upon the parent geologic formation. These groups of soils, such as the Clay-with-flints and the Thanet beds, have very definite agricultural properties; hence the treatment of all phases of agriculture upon each separate group of soils. Hall and Russell¹² present an excellent discussion of the methods of soil classification and the interpretation of the soil analyses used in their study. Russell¹³ gives a very similar though briefer treatment.

There are other more or less specialized classifications that have been applied to local conditions and problems. As an example may be cited Dickey's work on grape soils.¹⁴

Various modifications of the above schemes of classifying and mapping soils are found in general texts on soils.¹⁵ Nowacki¹⁶ proposes a curious system, *Genera et Species Terrarum*. It is in Latin terminology. The genera are based on the quality of the soil, whether stony, sandy, clayey, peaty, etc., and the species are dependent upon the quantities of organic matter and clay.

¹⁰ The Classification of Soils, Second Intern. Agrogeol. Conf., Stockholm, 1910, p. 231.

¹¹ London, Bd. Agr. and Fish., 1911.

¹² Jour. Agr. Science, vol. 4 (1911), pp. 182-223.

¹³ Soil Conditions and Plant Growth (London, Longmans, 1913), pp. 132-48.

¹⁴ Die ampelogeologische Kartierung. First Intern. Agrogeol. Cong., Budapest, 1909, pp. 257-71.

¹⁵ Ramann, E., Bodenkunde, Berlin, Springer, 1911.

Mitscherlich, E. A., Bodenkunde, Berlin, Parey, 1905.

¹⁶ Praktische Bodenkunde (Berlin, 1892), pp. 130-80.

Soil Surveying in the United States.—In a brief way, it has been shown how there arose the different systems of soil classification. Only a few typical systems of classifications, and something of the reasons for the divergences, have been mentioned.¹⁷ Probably the one agency that has carried on the most extensive soil classification and mapping is the Bureau of Soils of the United States Department of Agriculture. It is now proposed to discuss and in a measure criticize the work of the Bureau of Soils, the one organization that has, more than any other, succeeded in applying a detailed system of soil classification over extensive areas.

The problems that the Bureau had to face during its early existence were special studies of the soils of certain crops, especially of the tobacco districts.¹⁸ Later the soil utilization work of the Bureau of Soils was transferred to other branches of the Department of Agriculture, leaving as the main task for the Bureau the systematic classification and mapping of the soils of the United States.

Coffey¹⁹ has so well discussed the present day conceptions of the bases for the classification of soils, that it does not seem necessary to repeat any portion of that excellent statement here. He showed that the Bureau of Soils, in its method of classifying soils, uses a combination of a number of systems. This matter is dealt with more in detail in an article by Coffey,²⁰ and the Report of the Committee on Soil Classification of the American Society of Agronomy.²¹ The question often arises as to the validity of making the close distinctions regarding color, texture, geologic origin, etc., and is one which should be dealt with in order to render less empirical the nature of most of the criteria which are used at present. See the Report of the Committee on Soil Classification and Mapping.²²

Because of different views regarding soils and soil fertility from those held by the Bureau of Soils, the Illinois Agricultural Experiment Station has undertaken a soil survey and classification, under the direction of Dr. C. G. Hopkins, which is independent of the Bureau

¹⁷ See Coffey's excellent treatment of the soil survey work in this country. *The Development of Soil Survey Work in the United States with a Brief Reference to Foreign Countries*, Proc. Amer. Soc. Agron., vol. 3 (1911), pp. 115-29.

¹⁸ Whitney, *Extension and Practical Application of Soil Surveys*, Off. Exp. Sta., Bull. 142 (1903), pp. 111-12; *The Purpose of a Soil Survey*, U. S. Dept. Agr., Yearbook, 1901, pp. 117-32.

¹⁹ *A Study of the Soils of the United States*, U. S. Bur. Soils, Bull. 85 (1912), pp. 24-38.

²⁰ Jour. Amer. Soc. Agron., vol. 8 (1916), pp. 239-43.

²¹ *Ibid.*, vol. 6 (1914), pp. 284-88.

²² *Ibid.*, vol. 8 (1916), pp. 387-90.

of Soils, and differs from its methods in a number of ways. Since the soils of Illinois are of a much narrower range of variation than are those of the whole of the United States, the system of classification for the state need not be so elaborate. The soils are divided accordingly as they have been glaciated or not, and if glaciated, in what glaciation period. They are further divided according to color, topography, and texture of soil and subsoil.²³ Correlation of the types of soil mapped in the various areas, one of the greatest sources of criticism of the Bureau of Soils survey methods, is more easily handled in the Illinois work, since it is possible for the one in charge of the work to pass personally, while in the field, upon all correlation and the establishment of all new types. It is insisted that the field men map accurately and in sufficient detail. This insures the accuracy of the maps as regards the standards adopted, the information is specific, and the local users of the maps are not misled.²⁴ In connection with the field classification and mapping, pot and plot cultures are carried on, not so much to test the relative fertility of the untreated soils, but to determine the effects of the application of various sorts and quantities of fertilizers. Hopkins,²⁵ to show the differences in detail between the U. S. Bureau of Soils mapping and that of the Illinois Experiment Station, compares a U. S. Bureau survey of 1902 with a state survey published in 1911. This is not entirely fair, because with the increase of field knowledge of soils gained by them and the realization of the need of representing the soils in more detail, a survey made by the Bureau in 1911 would almost certainly show much more detail and show it with greater accuracy than the maps made in the early period of the work. This point may be strengthened by the notes given below on the comparison of a portion of an early survey made in southern California by the Bureau of Soils with a recent survey of the same soils made by the Bureau and the University of California working in coöperation.

PLAN OF THE PRESENT STUDY

The present study is an attempt to see if certain soil types mapped as the same from different areas in the state of California, and judged to be the same by the criteria used by the Bureau of Soils, are the

²³ Hopkins, *Soil Fertility and Permanent Agriculture* (Boston, Ginn, 1910), pp. 54-57.

²⁴ *Ibid.*, p. 115.

²⁵ *Ibid.*, pp. 114-15.

same or similar when examined from the laboratory standpoint. For example, we may take the Hanford fine sandy loam, which is one of the types that has been used in the present study. According to the criteria of color, mode of formation, origin (as judged by the presence of mica), nature of subsoil, texture, etc., this soil has been found and mapped in a number of areas that have been mapped in this state. But will these various bodies of soil, from widely separated portions of the state, when judged by laboratory and greenhouse studies on samples as nearly representative as possible, appear to be the same or similar?

The types selected for such a study as this should fulfil the following conditions: first, they should have at least a reasonably wide distribution in the state so as to have been mapped in a number of different soil survey areas; and second, the several types should be representative of different classes of soils (clays, loams, sandy loams, etc.), so that contrasts could be obtained between the types.

In the collection of samples it was aimed to obtain representative samples from each of a number of bodies of soil of the types selected; not to obtain possible variations from the ideal in any one body. In the laboratory the soils were compared with regard to their physical composition in the surface horizon, to their chemical composition in three horizons, and to their relative bacteriological activities. In the greenhouse the soils (surface horizon only) were placed in large pots and their comparative ability to produce various crops was studied.

No claim is made that these criteria should be the ones used in determining the systematic classification of soils or in determining the relative fertility of the soils. They were merely used to determine how nearly the soils classed under a given type name agree from the standpoints named.

DISCUSSION OF RESULTS

The bacteriological and chemical determinations were run in duplicate so that the figures presented are averages. It is considered that this gives fairer figures for comparison, especially since the determinations were run on separate samples, and not on aliquots of a single solution from a single sample.

There is a very important factor which should always be kept in mind especially when considering the bacteriological and greenhouse comparisons. This is the factor of the probable error. Though the

advisability of judging all results in the light of the probable error is admitted, no attempt has been made to apply this factor to the results reported in this paper. As the result of the effect which such a factor might have upon the results of bacteriological determinations carried on only in duplicate, or upon the results of greenhouse work done in triplicate, one hesitates to draw conclusions, especially those based upon minor variations. Hence in this work only the more marked results will be considered of significance.

When planning the work it was thought that three or four samples of a type would be enough to show whether or not a given type was approximately uniform, or widely variable, and as to whether the types were similar to one another, or quite dissimilar. But it now seems, after comparing the determinations run on the larger number of samples of the Hanford and San Joaquin types, 9 and 8 respectively, with the determinations run on the Altamont and Diablo types, of which there were a much smaller number of samples, 3 and 4 respectively, that the larger series gives a much better insight into the variations of a given type and affords a much better basis for conclusions.

Hence, as regards the laboratory work thus far carried out, the emphasis has been placed upon the Hanford fine sandy loam and the San Joaquin sandy loam. Determinations have not been completed on the Altamont and Diablo series to the extent that they have on the former two.

It is of no little significance that the Hanford fine sandy loam and the San Joaquin sandy loam are very widely contrasted soils agriculturally. The Hanford is typical of good recent alluvial soil in this state; while the San Joaquin is typical of wide expanses of "old valley filling" soils that are considered poor as regards crop producing power and are underlain by compact iron-cemented hardpan. Consequently, the results of comparing soils so different from an agricultural point of view, and so radically different as regards soil survey criteria (though the textures are quite similar) will be of considerable interest. They are of greater interest than the comparisons between the Diablo and Altamont soils, as the latter are quite similar in agricultural value and use, as well as in field appearances. Between the Diablo or Altamont and the Hanford or San Joaquin one cannot judge as closely regarding variations, for the soils are so radically different. On the other hand, one can compare the soils of the heavy and light types to see to what extent the chemical and bacteriological results differ as compared with the physical results.

Fig. 1. Graph showing the results of the Hilgard elutriator method of mechanical analysis on the four samples of Diablo clay adobe.

MECHANICAL ANALYSIS

Hilgard Elutriator Method.—That there is a wide variation between the samples is apparent (figs. 1-4). In fact, there is about as wide a range of differences among the samples of the Hanford

Fig. 2. Graph showing the results of the Hilgard elutriator method of mechanical analysis on the three samples of Altamont clay loam.

fine sandy loam and among those of the San Joaquin sandy loam as between the two types. The most outstanding differences are where they ought to be, to show the differences that the type names presuppose, i.e., in the "coarse sand" (64 mm.) and the "grits." The samples of the San Joaquin sandy loam average a larger proportion of each of these separates than do the Hanford fine sandy loam soils.

In the Hanford, no. 14 is notably heavier than the others, as shown by its silt content, which is nearly half again as great as that of the next highest sample.

The gravel content (sizes above 2 mm.) is interesting in its uniformity. In the San Joaquin soils the two samples above 1% are

Fig. 3. Graph showing the results of the Hilgard elutriator method of mechanical analysis on the eight samples of San Joaquin sandy loam.

nos. 11 and 26. The material in the latter soil is composed almost wholly of iron concretions, leaving sample no. 11 as the only soil with more than 1% actual gravel. In the Hanford samples none were found to have more than 1.5% gravel.

The Hilgard method does not include any precise subdivision of the soils into groups or classes according to texture. Dr. Hilgard was not in favor of making the fine distinctions in texture that other

investigators have emphasized. But if there were such a scheme, similar to that which the Bureau of Soils uses,²⁶ it would be an easy matter to compare the results obtained through the use of the elutriator, and determine whether or not the soils examined belong to a given class. The simple comparison of the quantities, in different

Fig. 4. Graph showing the results of the Hilgard elutriator method of mechanical analysis on the nine samples of Hanford fine sandy loam.

samples, of any given separate or separates is not absolute. For it must be realized that the conception of a soil class includes a certain range in the quantities of particles of the various sizes. This must be so since soils are ordinarily grouped into but ten or twelve class textures, while there exist among soils those with all gradations in the quantities of particles of the various sizes.

²⁶ Instructions to Field Parties, U. S. Bur. Soils, Bull. 1914, p. 75; *ibid.*, Bull. 85 (1912), p. 28.

And because the ranges in the sizes of the soil particles separated by the Bureau of Soils method cut across those of the Hilgard method, it is impossible to regroup the results so that the Bureau of Soils grouping into textures may be applied. But without any such scheme, desirable as it may be, it has been pointed out that there is clearly apparent a rather wide variation in the analyses of the several samples of a type. All the soils representative of a given type are by no means closely similar to one another.

TABLE 1.—COMPARISON OF TEXTURES

Texture as judged in the field	*Texture determined by mechanical analysis
*1 Diablo clay adobe	Clay
2 Diablo clay adobe	Clay
3 Altamont clay loam	*Silty clay
4 Altamont clay loam	Clay loam (sandy)
5 Diablo clay adobe	Clay
6 Diablo clay adobe	Clay
7 Altamont clay loam	Clay loam (heavy)
10 San Joaquin sandy loam	*Fine sandy loam
11 San Joaquin sandy loam	Sandy loam (heavy)
12 San Joaquin sandy loam	*Fine sandy loam
13 San Joaquin sandy loam	*Fine sandy loam (heavy)
14 Hanford fine sandy loam	Fine sandy loam (loam)
15 Hanford fine sandy loam	Fine sandy loam
16 Hanford fine sandy loam	*Sandy loam
17 San Joaquin sandy loam	Sandy loam
18 San Joaquin sandy loam	Sandy loam
19 Hanford fine sandy loam	*Sandy loam (heavy)
20 Hanford fine sandy loam	Fine sandy loam
21 Hanford fine sandy loam	Sandy loam
22 Hanford fine sandy loam	Fine sandy loam
23 Hanford fine sandy loam	Fine sandy loam
24 Hanford fine sandy loam	Fine sandy loam
25 Hanford fine sandy loam	Fine sandy loam
26 San Joaquin sandy loam	Sandy loam

NOTE.—Textures not judged correctly in the field.

Mechanical Analysis by the Bureau of Soils Method.—Among the other determinations made by the Division of Soil Technology on the surface horizons of the twenty-four soils used in this investigation was that of making the mechanical analysis. The tables show the percentages of the several separates. In all cases the figures represent averages of duplicate determinations and in some cases the averages of quadruplicate determinations. With this method, as well as with the Hilgard elutriator, there are shown wide variations between the

Fig. 5. Graph showing the results of the Bureau of Soils method of mechanical analysis on the four samples of Diablo clay adobe.

samples of a given type. But the graphs of the percentages (figs. 5-8), determined by the Bureau of Soils method for the several types are not as closely similar as the graphs of the elutriator results for the same types. That is, using the Bureau of Soils method, the graph of the Hanford fine sandy loam does not resemble that of the San Joaquin sandy loam as much as do the graphs of the results made

Fig. 6. Graph showing the results of the Bureau of Soils method of mechanical analysis on the three samples of Altamont clay loam.

upon the same soils by the Hilgard elutriator method. This would lead one to believe that the Bureau of Soils method of mechanical analysis is the better suited for separating soils into groups; even though these soils which were classified in the field according to the differences which are the more prominent would be expected to show greater differentiations when examined by the Bureau of Soils laboratory methods.

Comparison of Textures.—Table 1 gives the texture as shown on the soil survey map of the locality, as well as the results of the laboratory check. This texture as given on the map was also judged by me

Fig. 7. Graph showing the results of the Bureau of Soils method of mechanical analysis on the eight samples of San Joaquin sandy loam.

in the field to be more or less true to the type as mapped. I say more or less true, for the field notes, as given in appendix B, show that in several cases I was unable to obtain in the locality what I believed to

be a sample of the soil thoroughly typical of the class and type in question. Sample no. 3 had a large lime content which I thought might more or less obscure the texture. "Slightly heavy, and barely enough sand for a sandy loam" is the comment on sample 12, while "a heavy sandy loam, approaching a loam" is found in the notes on sample 13. The second column of the table shows the class subdivisions into which the soils were placed according to the mechanical analysis. The words in parenthesis show modifying conditions but do not indicate a change in the class. In considering the class groups such as sandy loam, fine sandy loam, etc., it should be remembered that though the groups are rather broad, the limits are arbitrary and quite sharp. So the results of a mechanical analysis may place a soil in the sandy loam class if 25% or more is fine gravel, coarse and medium sand, while if less than 25% be present the soil belongs to the fine sandy loam class, providing at the same time the amounts of silt, clay, and fine sand are within the specified limits. The two soils may be a great deal alike in texture though placed in different classes. The failure of my judgment regarding the texture shows one of the difficulties that the field man is continually facing. And his failure to judge textures correctly is one of the causes of criticism of soil survey work.

TABLE 2—MECHANICAL ANALYSES, HILGARD ELUTRIATOR METHOD

Diablo Clay Adobe

Name	Separates		Samples			
	Diameter, mm.	Velocity, mm. per second	1-A %	2-A %	5-A %	6-A %
Clay	.01	0.25	44.16	35.81	44.97	64.63
Fine silt	.01-.016	0.25	23.91	34.08	25.57	25.13
Medium silt	.016-.025	0.5	5.97	7.37	4.14	1.03
	.025-.036	1	8.10	9.09	5.28	1.83
Coarse silt	.036-.047	2	7.77	7.47	5.45	1.99
	.047-.072	4	6.05	4.09	6.18	2.13
Fine sand	.072-.12	8	3.28	1.33	5.81	2.07
	.12-.16	16	0.48	0.43	1.73	0.90
Medium sand	.16-.30	32	0.08	0.21	0.38	0.21
Coarse sand	.30-.50	64	0.18	0.11	0.49	0.11
Total weight of separates, gm.			19.18	19.62	19.30	19.68
Weight of original sample, gm.			18.83	18.88	18.66	18.16
Grits, %	0.5-2.0 mm.		0.26	0.29	0.57	0.10
Hygroscopic moisture, %			6.20	5.93	7.18	10.12

Fig. 8. Graph showing the results of the Bureau of Soils method of mechanical analysis on the nine samples of Hanford fine sandy loam.

TABLE 3—MECHANICAL ANALYSES, HILGARD ELUTRIATOR METHOD

Altamont Clay Loam

Name	Separates		Samples		
	Diameter mm.	Velocity mm. per second	3-A %	4-A %	7-A %
Clay	.01	0.25	28.48	26.41	22.65
Fine silt	.01-.016	0.25	43.42	17.73	41.18
Medium silt	.016-.025	0.5	2.96	2.39	4.67
	.025-.036	1	4.37	4.82	8.51
Coarse silt	.036-.047	2	4.95	4.89	6.01
	.047-.072	4	5.52	7.52	7.90
Fine sand	.072-.12	8	5.14	8.83	5.54
	.12-.16	16	3.89	13.61	1.98
Medium sand	.16-.30	32	0.88	10.40	0.95
Coarse sand	.30-.50	64	0.21	3.39	0.61
Total weights of separates, gm.			18.71	19.54	20.96
Weight of original sample, gm.			18.50	19.16	19.21
Grits, % 0.5-2.0 mm.			3.98	8.09	1.63
Hygroscopic moisture, %			8.08	4.37	4.09

TABLE 4—MECHANICAL ANALYSES, HILGARD ELUTRIATOR METHOD

San Joaquin Sandy Loam

Name	Separates		Samples							
	Diameter mm.	Velocity, mm. per second	10-A %	11-A %	12-A %	13-A %	17-A %	18-A %	21-A %	26-A %
Clay	.01	0.25	11.14	15.46	8.99	10.75	10.53	8.72	8.35	16.64
Fine silt	.01-.016	0.25	20.24	31.88	26.57	24.04	16.20	18.56	14.73	20.78
Medium silt	.016-.025	0.5	1.44	2.73	2.31	4.64	1.81	3.06	3.54	3.83
	.025-.036	1	6.54	9.11	1.33	9.86	5.89	6.93	6.98	9.24
Coarse silt	.036-.047	2	8.36	10.23	1.19	9.59	5.82	6.90	7.10	7.00
	.047-.072	4	9.50	8.41	10.14	10.05	8.46	8.45	7.67	8.89
Fine sand	.072-.12	8	10.66	7.47	10.72	10.92	12.04	9.72	12.86	5.77
	.12-.16	16	10.30	5.97	10.88	16.14	13.43	10.56	13.53	3.85
Medium sand	.16-.30	32	14.69	6.91	11.75	1.96	19.21	16.59	13.05	0.86
Coarse sand	.30-.50	64	7.11	1.32	3.54	2.12	6.60	10.50	12.14	23.04
Total weight of separates, gm.			20.02	20.44	19.99	20.10	20.38	20.06	20.33	20.14
Weight of original sample, gm.			19.80	19.51	19.72	19.76	19.85	19.86	19.85	19.69
Grits, % 0.5-2.0 mm.			16.70	23.54	8.84	8.10	23.12	32.00	28.50	36.00
Hygroscopic moisture, %			0.98	2.48	1.38	1.22	0.75	0.70	0.75	1.57

NOTE.—All weighings made on the water free basis.

TABLE 5—MECHANICAL ANALYSES, HILGARD ELUTRIATOR METHOD

Hanford Fine Sandy Loam

Separates			Samples								
Name	Diameter mm.	Velocity, mm. per second	14-A	15-A	16-A	19-A	20-A	22-A	23-A	24-A	25-A
			%	%	%	%	%	%	%	%	%
Clay	.01	0.25	12.89	8.16	11.97	11.09	10.55	7.97	8.68	6.47	6.65
Fine silt	.01-.016	0.25	37.25	19.39	24.61	5.95	22.09	14.15	22.57	11.11	14.54
Medium silt	.016-.025	0.5	4.19	3.05	3.22	1.67	6.40	3.15	5.90	1.20	1.59
	.025-.036	1	8.63	5.04	5.06	5.27	8.40	5.29	6.89	5.08	6.36
Coarse silt	.036-.047	2	7.95	6.57	5.99	7.14	7.68	6.47	10.53	7.48	7.91
	.047-.072	4	6.23	10.23	7.27	12.76	9.93	11.30	13.03	13.91	12.64
Fine sand	.072-.12	8	5.26	12.31	8.57	17.79	10.48	17.15	12.71	19.27	18.11
	.12-.16	16	7.15	13.93	9.76	12.00	12.29	17.39	7.94	21.56	9.55
Medium sand	.16-.30	32	8.81	15.29	16.05	24.20	10.03	14.87	9.88	12.36	19.15
Coarse sand	.30-.50	64	1.43	6.02	7.51	2.13	2.70	2.27	1.85	1.50	3.50
Total weight of separates, gm.			20.19	20.23	20.53	20.08	20.27	20.06	20.30	20.26	19.18
Weight of original sample, gm.			19.46	19.90	19.69	19.82	19.73	19.81	19.78	19.83	19.78
Grits, %			4.12	13.23	25.47	7.85	6.71	3.07	7.24	6.85	3.83
Hygroscopic moisture, %			2.73	0.49	1.54	0.89	1.34	0.94	1.10	0.84	1.10

TABLE 6—MECHANICAL ANALYSES, BUREAU OF SOILS METHOD

Diablo Clay Adobe

Separates		Samples			
Name	Diameter mm.	1-A %	2-A %	5-A %	6-A %
Clay	.005	44.81	44.44	45.67	56.01
Silt	.005-.05	32.00	42.51	23.01	14.28
Very fine sand	.05-.10	19.61	11.35	21.58	25.58
Fine sand	.10-.25	1.36	1.33	4.81	2.10
Medium sand	.25-.5	0.26	0.69	0.95	2.05
Coarse sand	.5-1.0	0.58	0.20	1.56	0.00
Fine gravel	1.0-2.0	0.03	0.02	0.04	0.00

NOTE.—Determinations made by the Division of Soil Technology.

TABLE 7—MECHANICAL ANALYSES, BUREAU OF SOILS METHOD

Altamont Clay Loam

Separates		Samples		
Name	Diameter mm.	3-A %	4-A %	7-A %
Clay	.005	33.19	26.50	31.84
Silt	.005-.05	31.76	17.35	37.40
Very fine sand	.05-.10	22.81	39.15	24.70
Fine sand	.10-.25	8.97	6.08	3.27
Medium sand	.25-.5	1.99	7.78	0.92
Coarse sand	.5-1.0	1.74	3.06	0.55
Fine gravel	1.0-2.0	1.01	1.22	0.22

NOTE.—Determinations made by the Division of Soil Technology.

TABLE 8—MECHANICAL ANALYSES, BUREAU OF SOILS METHOD

San Joaquin Sandy Loam

Separates		Samples							
Name	Diameter mm.	10-A %	11-A %	12-A %	13-A %	17-A %	18-A %	21-A %	26-A %
Clay	.005	10.78	15.77	16.16	16.94	11.77	10.49	8.28	17.38
Silt	.005-.05	21.60	35.97	25.04	22.70	15.97	26.74	17.70	18.17
Very fine sand	.05-.10	28.07	18.53	27.42	47.01	20.42	12.02	15.92	13.84
Fine sand	.10-.25	19.96	2.66	17.07	3.99	22.57	16.61	21.27	10.26
Medium sand	.25-.5	9.20	6.96	5.80	4.69	10.75	13.85	13.57	14.72
Coarse sand	.5-1.0	9.08	8.51	6.52	2.96	13.81	16.52	21.41	24.26
Fine gravel	1.0-2.0	1.34	12.52	2.15	1.81	3.13	4.07	2.07	2.02

NOTE.—Determinations made by the Division of Soil Technology.

TABLE 9—MECHANICAL ANALYSES, BUREAU OF SOILS METHOD

Hanford Fine Sandy Loam

Separates		Samples								
Name	Diameter mm.	14-A %	15-A %	16-A %	19-A %	20-A %	22-A %	23-A %	24-A %	25-A %
Clay	.005	14.10	12.08	16.84	15.28	15.95	7.79	10.61	9.83	7.60
Silt	.005-.05	39.25	22.42	16.16	15.03	32.90	22.70	24.38	11.42	12.90
Very fine sand	.05-.10	22.66	37.12	16.46	32.87	22.58	36.15	38.73	42.05	67.37
Fine sand	.10-.25	17.54	6.51	17.32	8.13	18.20	27.78	16.51	28.73	5.88
Medium sand	.25-.5	4.71	11.40	11.70	15.42	4.97	4.21	4.66	4.27	3.47
Coarse sand	.5-1.0	1.99	8.49	15.54	9.27	3.07	1.47	3.28	3.01	1.27
Fine gravel	1.0-2.0	0.13	1.91	5.27	3.63	0.20	0.20	1.48	1.02	1.02

NOTE.—Determinations made by the Division of Soil Technology.

Moisture Equivalent.—The moisture equivalents of the surface horizon samples were determined by the Division of Soil Technology (table 10, and figs. 9, 10). The different types gave quite distinct averages, though there was considerable variation within the type. The Diablo clay adobe varied from 37% to 57%, with an average of 47%. The Altamont clay loam varied from 22% to 37%, with 28% as an average. The San Joaquin sandy loam varied from 7% to 15%, with the average of 11%. The Hanford fine sandy loam varied from 11% to 25%, with 15% as the average. These figures show that as a whole the moisture equivalents of the several types are distinct, though there is the usual overlapping in some cases. The samples of a given type are in many instances closely similar, though not always or even usually so.

Fig. 9. Graph showing the results of the determination of the moisture equivalent and of the hygroscopic coefficient on the four samples of Diablo clay adobe and the three samples of Altamont clay loam.

TABLE 10—MOISTURE EQUIVALENT

Diablo Clay Adobe			Altamont Clay Loam			San Joaquin Sandy Loam			Hanford Fine Sandy Loam		
No.	%	Average %	No.	%	Average %	No.	%	Average %	No.	%	Average %
1-A	49.70		3-A	38.10		10-A	10.30		14-A	25.80	
	48.90	49.30		37.80	37.95		10.10	10.20		25.20	25.50
2-A	37.40		4-A	23.41		11-A	15.52		15-A	11.50	
	36.80	37.10		22.35	22.88		15.54	15.53		11.20	11.35
5-A	46.55		7-A	23.90		12-A	13.72		16-A	15.60	
	48.10	47.32		23.90	23.90		13.62	13.67		15.60	15.60
6-A	58.80		Average 28.94			13-A	14.50		19-A	13.30	
	56.80	57.80					14.60	14.55		14.30	13.80
Average 47.88						17-A	8.90		20-A	18.41	
							8.98	8.94		18.38	18.39
						18-A	7.92		22-A	12.73	
							7.87	7.89		12.22	12.47
						21-A	7.16		23-A	11.08	
							7.09	7.12		10.90	10.99
						26-A	11.30		24-A	16.30	
							11.81	11.55		16.17	16.23
						Average 11.18			25-A	11.17	
										12.72	11.94
									Average 15.14		

NOTE.—Determinations made by the Division of Soil Technology.

TABLE 11—HYGROSCOPIC COEFFICIENT

Diablo Clay Adobe			Altamont Clay Loam			San Joaquin Sandy Loam			Hanford Fine Sandy Loam		
No.	%	Average %	No.	%	Average %	No.	%	Average %	No.	%	Average %
1-A	15.88		3-A	17.48		14-A	5.35		10-A	2.46	
	15.08	15.48		18.45	17.93		4.70	5.03		2.51	2.49
2-A	9.90		4-A	9.60		15-A	1.31		11-A	3.44	
	9.48	9.69		7.00	8.30		1.39	1.35		3.45	3.44
5-A	14.18		7-A	7.92		16-A	3.90		12-A	3.58	
	13.90	14.04		5.92	6.92		3.60	3.75		3.45	3.52
6-A	15.20		Average 11.05			19-A	1.66		13-A	2.50	
	15.70	15.45					1.80	1.73		2.60	2.55
Average 13.66						20-A	2.90		17-A	1.84	
							3.02	2.96		1.62	1.73
						22-A	2.48		18-A	2.10	
							2.89	2.69		2.00	2.05
						23-A	2.38		21-A	1.98	
							2.53	2.46		1.92	1.95
						24-A	2.39		26-A	3.57	
							2.39			3.52	3.55
							2.37	2.38	Average 2.66		
						25-A	1.78				
							1.84	1.81			

NOTE.—Determinations made by the Division of Soil Technology.

Fig. 10. Graph showing the results of the determination of the moisture equivalent and of the hygroscopic coefficient on the eight samples of San Joaquin sandy loam and the nine samples of Hanford fine sandy loam.

Hygroscopic Coefficient.—The determination of this coefficient, also by the Division of Soil Technology, shows no very distinct values for the several types under consideration (table 11, figs. 9,10). The Diablo clay adobe samples vary from 9.6% to 15.4%, with the average of 13.6%. The Altamont clay loam samples vary from 6.9% to 17.9%, averaging 11%. The San Joaquin sandy loam varies from

1.7% to 3.5%, with the average of 2.66%, while the Hanford fine sandy loam varies from 1.3% to 5%, with the average of 2.68%. There is no question that here the range of values within every type is greater than that from type to type. Even excluding those samples shown by the mechanical analysis to be not true to name there is a wide range within each type—a range too wide to allow one to answer the question of this paper in the affirmative.

Fig. 11. Graph showing the percentages of nitrogen and of phosphorus in the four samples of Diablo clay adobe.

THE CHEMICAL DATA

TOTAL NITROGEN

Diablo clay adobe.—There is more variation in nitrogen content between the different representatives of the type than one would expect from a visual examination of the soils (table 12 and fig. 11). No. 2 would be expected to contain less nitrogen than no. 5 because of the lighter color, but such is not the case. In the A horizon, no. 5 shows the lowest total nitrogen content with 0.084%, no. 2 is higher with 0.092%, no. 1 with 0.104%, and no. 6 is the highest with 0.117%. The decrease in the nitrogen content with the increase in depth is normal. In the C horizon, no. 1 has the lowest total nitrogen content with 0.057%, and no. 6 the highest, with 0.078%.

Altamont clay loam.—The agreement between the A samples is fairly close (table 13, and fig. 12). No. 4 has 0.103%, no. 7, 0.104%, and no. 3 has 0.123%. This gives an average for the surface soil of 0.110%, as compared with 0.099% in the Diablo clay adobe. It is to be noted that the nitrogen content of the subsoil is relatively less than that in the Diablo subsoils, 0.071% and 0.056% in the Altamont B and C horizons, respectively, as against 0.076% and 0.065% in the

B and C horizons of the Diablo. The average amount of nitrogen is higher in the A horizon of the Altamont than in the Diablo, contrary to what one would expect from the color of the soils, since the Altamont is typically a brown soil and the Diablo a dark gray to black soil.

San Joaquin sandy loam.—The nitrogen content of these soils is uniformly low (table 14 and fig. 13), from 0.03% to 0.05%, and is but a third to a half of what Hilgard believed adequate for crop production.

Fig. 12. Graph showing the percentages of nitrogen and of phosphorus in the three samples of Altamont clay loam.

Fig. 13. Graph showing the percentages of nitrogen and of phosphorus in the eight samples of San-Joaquin sandy loam.

The nitrogen content is seen to vary more or less directly with the amount of the finer sediments present in the soil—nos. 11 and 12 being heavy members of the type, with 0.05% and 0.047% respectively, and nos. 17 and 18 light members of the type with 0.029% and 0.027% respectively. It may be noted that the nitrogen content of the various horizons are not as far apart as in the other types. The averages for the three horizons are: A—0.037%, B—0.027%, and C—0.026%. It must be borne in mind that the San Joaquin sandy loam horizons are not full 12-inch samples, and that the total depth of the sampling is less.

Hanford fine sandy loam.—Here again in the A horizon the nitrogen content is fairly uniform (table 15, and fig. 14), with from 0.045% to 0.072%, if the extra typical no. 14, with 0.119%, be left out of consideration. One would suppose these soils to be higher in their

Fig. 14. Graph showing the percentages of nitrogen and of phosphorus in the nine samples of Hanford fine sandy loam.

nitrogen content, as compared with the San Joaquin series, than the results show. The B and C horizons of the Hanford samples contain 0.038% and 0.028% nitrogen, respectively, showing that with the increase of depth there is a more rapid decrease of nitrogen than in the San Joaquin samples, with the nitrogen content of the C horizon of the Hanford only 0.002% above that of the C horizon of the San

Joaquin. The greenhouse pot cultures showed the effect of the much higher nitrogen content in no. 14 in giving better color and growth to the plants and especially to the grains. The increase of the nitrogen in the surface of no. 23, as compared with the B and C horizons, might be ascribed to the fertilizers applied to the orange grove where this sample was collected; yet no. 24 is a truck soil which has been fertilized to a considerable extent with barnyard manure. The nitrogen content of this type, as judged by the previous standards, is quite inadequate.

Compare the nitrogen content of the A horizons of the four types: The Diablo has an average of 0.099%, with a range of from 0.084% to 0.117%; the Altamont has an average of 0.110%, with a range of from 0.103% to 0.123%; the San Joaquin has an average of 0.037%, with a range of from 0.027% to 0.050%; and the Hanford has an average of 0.062%, with a range of from 0.045% to 0.119%. Thus the total nitrogen content of the several types is reasonably constant within the type and rather distinct for the types.

TABLE 12—TOTAL NITROGEN

Diablo Clay Adobe

Sample	Horizon					
	A %	Average %	B %	Average %	C %	Average %
1	0.109	0.105	0.076	0.069	0.056	0.057
2	0.101		0.063		0.059	
	0.100		0.072		0.062	
5	0.084	0.092	0.064	0.068	0.058	0.060
	0.085		0.065		No sample	
6	0.084	0.084	0.065	0.065		
	0.114		0.097		0.075	
	0.122	0.118	0.107	0.102	0.083	0.079
Average		0.100		0.076		0.065

TABLE 13—TOTAL NITROGEN

Altamont Clay Loam

Sample	Horizon					
	A %	Average %	B %	Average %	C %	Average %
3	0.123		0.089		0.069	
	0.124	0.123	0.087	0.088	0.067	0.068
4	0.103		0.054		0.041	0.041
	0.103	0.103	0.053	0.053	0.041	0.041
7	0.106		0.070		0.061	
	0.104	0.105	0.077	0.073	0.059	0.060
Average		0.110		0.071		0.056

TABLE 14—TOTAL NITROGEN

San Joaquin Sandy Loam

Sample	Horizon					
	A %	Average %	B %	Average %	C %	Average %
10	0.037		0.026		0.022	
	0.038	0.037	0.029	0.027	0.020	0.021
11	0.051		0.042		0.038	
	0.051	0.051	0.046	0.044	0.040	0.039
12	0.049		0.032		0.042	
	0.045	0.047	0.034	0.033	0.040	0.041
13	0.040		0.038		0.033	
	0.040	0.040	0.043	0.040	0.033	0.033
17	0.028		0.019		No sample	
	0.030	0.029	0.018	0.018		
18	0.028		0.016		0.018	
	.....	0.028	0.017	0.016	0.021	0.019
21	0.029		0.012		0.014	
	0.030	0.029	0.012	0.012	0.014	0.014
26	0.041		0.026		0.016	
	0.041	0.041	0.027	0.026	0.017	0.016
Average		0.038		0.027		0.026

TABLE 15—TOTAL NITROGEN

Hanford Fine Sandy Loam

Sample	Horizon					
	A %	Average %	B %	Average %	C %	Average %
14	0.113		0.084		0.060	
	0.126	0.119	0.081	0.082	0.057	0.058
15	0.052		0.039		0.028	
	0.055	0.053	0.043	0.041	0.027	0.028
16	0.058		0.030		0.020	
	0.054	0.056	.....	0.030	0.023	0.021
19	0.046		0.025		0.024	0.023
	0.044	0.045	0.025	0.025	0.023	0.023
20	0.062		0.032		0.024	
	0.058	0.060	0.034	0.033	0.022	0.023
22	0.057		0.033		0.025	
	0.061	0.059	0.036	0.034	0.023	0.024
23	0.075		0.028		0.020	
	0.071	0.073	0.030	0.029	0.016	0.018
24	0.050		0.032		0.028	0.028
	0.045		0.031		0.022	
25	0.047		0.032		0.024	
		0.046		0.031		0.023
Average		0.062		0.038		0.027

HUMUS

Diablo clay adobe.—The variations in the humus content of the A samples (table 16, and fig. 15) are moderate, 1.1% to 1.4%, while the B and C horizons do not agree so closely with each other or with the

Fig. 15. Graph showing the loss on ignition, the amount of humus, and the percentages of calcium, magnesium, and potassium in the four samples of Diablo clay adobe.

surface foot. The average content of humus in the A samples is 1.26%, in the B samples 0.95%, and in the C samples 0.75%. It is worthy of note that soil no. 2, with the lightest color of the four, and what might be supposed to be a lower humus content, has next to the highest amount.

Altamont clay loam.—Here the variations in the humus content (table 17, and fig. 16) are small in the A horizon, 1.1% to 1.3%. The average is 1.24%. The B and C samples show a good parallelism among themselves, but not so good when compared with the surface. The average of the B horizon is 0.84%, and of the C horizon 0.57%.

Fig. 16. Graph showing the loss on ignition, the amount of humus, and the percentages of calcium, magnesium, and potassium in the three samples of Altamont clay loam.

San Joaquin sandy loam.—This type contains a considerable quantity of humus (table 18, and fig. 17) when one takes into consideration the popular criteria for the presence of humus, for the reddish brown San Joaquin soils are very different from the brown Altamont or the black Diablo soils. The samples of this type gave

light colored or nearly colorless humus solutions. But when the aliquots were ignited, after evaporation, there was a very noticeable blackening and charring of the residue, together with a considerable

Fig. 17. Graph showing the loss on ignition, the amount of humus, and the percentages of calcium, magnesium, and potassium in the nine samples of San Joaquin sandy loam.

loss in weight. This phenomenon, in the light of the work of Gortner,²⁷ shows that these soils have a "humus" content above that which they might be supposed to have, because of the almost complete absence of

²⁷ Soil Science, vol. 2 (1916), pp. 395-442.

the "black pigment." Soil no. 26, probably the only virgin soil in the series, shows a particularly high content of humus for such a soil, though from the color of the soil one would suspect but very little humus. The agreement between the three horizons of the San Joaquin sandy loam samples is close. The average content of humus was 0.68% in the A, 0.51% in the B, and 0.38% in the C horizon.

Hanford fine sandy loam.—The variations in humus content in this type are greater than in any of the others (table 19, and fig. 18). This is possibly because of two factors: the open texture of the soil, hence the rapid loss of organic matter by oxidation processes; and secondly, the high agricultural value of this soil, which has led to a greater application of fertilizers than has been the case with the other soils. The actual variations in the humus content are large, 0.7% to 2.1% with the average of 1.15% for horizon A, from 0.5% to 1.8% with the average of 0.81% for B, and from 0.44% to 1.07% with the average of 0.59% for C. The extra-typical sample no. 14 is above any of the others in the total humus content. The variations in the subsoil humus content are more or less parallel to those of the surface soil.

The following averages of the humus content of horizon A, Diablo 1.26%, Altamont 1.24%, San Joaquin 0.68%, Hanford 1.15%, show that there is not much difference between the soils, except for the San Joaquin sandy loam, which has an average of half the others. Within the type the soils may be nearly alike, as in the San Joaquin and Altamont, or may be variable to a large degree, as in the Hanford. The variations in the humus content of the soils are small, considering the diverse nature of the soils, and the usual methods for judging the quantity of humus.

TABLE 16—HUMUS (AND HUMUS ASH)

Diablo Clay Adobe

Sample	Humus Horizons						Humus ash Horizons					
	A %	Average %	B %	Average %	C %	Average %	A %	Average %	B %	Average %	C %	Average %
1	1.08		0.51			0.18	0.55		0.75		0.45	
	1.08	1.08	0.51	0.51	0.24	0.21	0.56	0.56	0.73	0.74	0.46	0.46
2	1.40		1.16		1.09		1.01		0.96		1.09	
	1.38	1.39	1.15	1.15	1.02	1.06	1.03	1.02	0.96	0.96	0.96	1.03
5	1.17		0.87		.....		1.08		1.19		.....	
	1.12	1.15	0.91	0.89	.....	.....	1.10	1.09	1.14	1.17	.....	.....
6	1.48		1.26		0.95		0.98		0.88		0.78	
	1.37	1.43	1.26	1.26	0.99	0.97	0.95	0.96	0.91	0.90	0.85	0.81
Average		1.26		0.95		0.72		0.91		0.95		0.77

Fig. 18. Graph showing the loss on ignition, the amount of humus, and the percentages of calcium, magnesium, and potassium in the nine samples of Hanford fine sandy loam.

TABLE 17—HUMUS (AND HUMUS ASH)

Altamont Clay Loam

Sample	Humus Horizons						Humus ash Horizons					
	A %	Average %	B %	Average %	C %	Average %	A %	Average %	B %	Average %	C %	Average %
3	1.06		0.89		0.59		1.29		1.08		0.95	
	1.13	1.09	0.84	0.86	0.58	0.59	1.23	1.26	1.28	1.18	0.95	0.95
4	1.30		0.69		0.59		0.80		0.98		0.91	
	1.33	1.31	0.71	0.70	0.28	0.43	0.85	0.83	0.98	0.98	1.03	0.97
7	1.32		0.95		0.68		0.72		0.87		1.09	
	1.31	1.32	0.96	0.96	0.68	0.68	0.75	0.74	0.88	0.88	1.08	1.08
Average		1.24		0.84		0.57		0.94		1.01		1.00

TABLE 18—HUMUS (AND HUMUS ASH)

San Joaquin Sandy Loam

Sample	Humus Horizons						Humus ash Horizons					
	A %	Average %	B %	Average %	C %	Average %	A %	Average %	B %	Average %	C %	Average %
10	0.66		0.53		0.27		1.31		1.33		0.67	
		0.66		0.53		0.27		1.31		1.33		0.67
11	0.75		0.41		0.37		0.51		0.66		0.58	
	0.71	0.73		0.41		0.37	0.69	0.60		0.66		0.58
12	0.62		0.49		0.32		0.88		1.50		0.80	
	0.65	0.64		0.49		0.32	0.95	0.91		1.50		0.80
13	0.75		0.50		0.35		1.38		0.90		1.02	
	0.78	0.77		0.50		0.35	1.36	1.37		0.90		1.02
17	0.51		0.38				0.53		1.23			
	0.51	0.51		0.38			0.57	0.55		1.23		
18	0.56		0.60		0.42		0.61		0.76		1.79	
	0.60	0.58	0.58	0.59		0.42	0.56	0.59	0.75	0.76		1.79
21	0.52		0.19		0.18		0.53		0.37		0.37	
	0.52	0.52	0.21	0.40	0.21	0.19	0.54	0.53	0.37	0.37	0.48	0.42
26	1.04		0.79		0.68		0.89		3.57		5.28	
	1.01	1.02	0.79	0.79	0.82	0.75	0.76	0.83	3.60	5.46	5.35	
Average		0.66		0.51		0.38		0.83		1.24		1.51
Excluding no. 26									0.95			0.87

LOSS ON IGNITION

The loss on ignition of the A horizon varies directly with the texture of the soil, the heavier soils losing more on heating. Obviously the water of combination of the clay is a large factor in this loss. In the San Joaquin sandy loam the loss on ignition was determined in the three horizons. In the other three types the A horizon was the only one examined (tables 20, 21, and figs. 15-18).

TABLE 19—HUMUS (AND HUMUS ASH)

Hanford Fine Sandy Loam

Sample	Humus Horizons						Humus ash Horizons					
	A %	Average %	B %	Average %	C %	Average %	A %	Average %	B %	Average %	C %	Average %
14	2.11		1.81		1.10		1.14		1.24		1.01	
	2.09	2.10	1.78	1.79	1.05	1.07	1.17	1.16	1.27	1.26	1.09	1.05
15	1.79		0.88		1.04		1.88		0.94		0.92	
	1.77	1.78	0.93	0.90	0.67	0.86	1.85	1.86	0.89	0.92	0.91	0.92
16	1.20		0.73		0.41		0.91		0.93		0.90	
	1.20	1.20	0.73	0.73	0.46	0.44	0.91	0.91	1.47	0.93	0.90	0.90
19	0.73		0.51		0.45		0.48		0.57		0.78	
	0.74	0.73	0.50	0.51	0.55	0.50	0.47	0.48	0.58	0.58	0.76	0.77
20	1.08		0.86		0.59		0.52		0.90		0.79	
	1.06	1.07	0.89	0.88	0.50	0.55	0.56	0.54	0.90	0.90	0.78	0.78
22	0.96		0.73		0.58		0.59		0.60		0.58	
	0.96	0.96	0.71	0.72	0.56	0.57	0.59	0.59	0.60	0.60	0.63	0.61
23	1.04		0.59		0.38		0.58		0.45		0.39	
	1.07	1.05	0.62	0.61	0.38	0.38	0.57	0.58	0.41	0.43	0.37	0.38
24	0.73		0.55		0.56		0.58		0.69		0.82	
	0.73	0.73	0.61	0.58	0.51	0.54	0.56	0.57	0.69	0.69	0.80	0.81
25	0.71		0.58		0.45		0.57		0.67		0.74	
	0.69	0.70	0.56	0.57	0.42	0.44	0.61	0.59	0.71	0.69	0.78	0.76
Average		1.15		0.82		0.59		0.81		0.78		0.78

Diablo clay adobe.—The variation in these samples was from 5.6% to 8.6%, with the average of 6.8%. The Altamont clay loam has a variation of from 5% to 8.7%, averaging 6.7%. The San Joaquin sandy loam has a range of variation between 1.6% and 4.2%, with an average of 2.6%. The loss on ignition of the lower horizons increases over that of the surface, because of the increase in texture. The B horizon shows an average loss of 3.9% and the C horizon of 4.67%. The Hanford fine sandy loam range of variation in the loss on ignition is, excluding no. 14, from 2.2% to 3.9%, with an average of 3.4%. Thus the curve for this type is quite uniform, except for no. 14, which shows a loss of 6.9%.

It is seen that the averages in the loss on ignition of the A horizons of the Diablo and Altamont soils are close, and high, 6.8% and 6.7% respectively. The averages of the San Joaquin and Hanford samples, 2.6% and 3.4% respectively, are low and not widely separated. Since the values for the types overlap considerably, and the averages are not distinct, except between the light and heavy groups, there is no significant distinction between the four types by this determination.

TABLE 20—LOSS ON IGNITION

(Surface horizon only)

Diablo Clay Adobe			Altamont Clay Loam			Hanford Fine Sandy Loam		
	%	%		%	%		%	%
1-A	6.62		3-A	8.74		14-A	6.90	
	6.66	6.64		8.82	8.78		6.95	6.92
2-A	6.57		4-A	5.05		15-A	2.27	
	6.64	6.60		5.05	5.05		2.30	2.28
5-A	5.61		7-A	6.58		16-A	3.26	
	.....	5.61		6.46	6.52		3.24	3.25
6-A	8.67		Average	6.78		19-A	3.10	
	8.71	8.69					3.13	3.11
Average		6.88				20-A	3.90	
							3.94	3.92
						22-A	3.06	
							3.07	3.06
						23-A	3.48	
							3.45	3.46
						24-A	2.60	
							2.60	2.60
						25-A	2.68	
							2.72	2.70
						Average		3.48

TABLE 21—LOSS ON IGNITION

San Joaquin Sandy Loam

Sample	Horizon					
	A %	Average %	B %	Average %	C %	Average %
10	2.13		2.32		3.10	
	2.17	2.15	2.27	2.29	3.08	3.09
11	3.23		6.33		6.57	
	3.20	3.21	6.16	6.24	6.67	6.62
12	5.37		2.97		.....	
	3.22	4.20	3.18	3.07	5.54	5.54
13	2.94		6.58		3.97	
	2.96	2.95	6.75	6.66	6.07	5.02
17	1.85		2.54		No sample	
	1.88	1.86	2.61	2.57		
18	1.82		2.18		2.90	
	1.83	1.82	2.18	2.18	2.89	2.89
21	1.68		1.60		3.31	
	1.69	1.68	1.56	1.58	3.33	3.32
26	3.30		6.97		6.18	
	.....	3.30	6.95	6.96	.....	6.18
Average		2.66		3.94		4.67

CALCIUM

The Diablo, Altamont, and Hanford soils were analyzed for their calcium in the A horizon only, while the A, B, and C horizons of the San Joaquin sandy loam were analyzed (tables 22, 23, and figs. 15-18).

Diablo clay adobe.—There is much divergence in the amounts of CaO in this type, varying from 0.36% to 2.05%, with the average of 1.23%.

Altamont clay loam.—In this type there is a little greater variation than in the Diablo samples, with a range of from 0.78% to 5.64%, averaging 2.44% CaO. In both this soil and in the Diablo the wide variation in the lime content is undoubtedly due to the nature of the parent rock, since the soils are residual.

San Joaquin sandy loam.—In the CaO content there is no uniformity among the samples. The A samples of this type contain from 0.47% to 2.98%, with an average of 1.65%. It would seem that the materials from which the soils were derived were of varying composition. For from the present climatic conditions soil no. 25 is the one subject to the least leaching, and yet has the least CaO content. The B and C percentages follow the surface very closely—sufficiently so to necessitate no particular explanation. The range of variation in the B horizon is from 0.11% to 2.42%, and the average is 1.42%. The C samples vary from 0.17% to 2.81%, with the average of 1.52%.

Hanford fine sandy loam.—The A samples of this type contain from 2.56% CaO to 4.69%, with 3.33% as the average. The variations are not so marked among the series of this type as in the cases of the other three soils. The absolute range is nearly as great, but the relative variation is less.

Even though there are differences between the average CaO content in the several types, the wide variation in the amount found in the several samples of a given type, and the overlapping of these amounts from the different types entirely preclude any statement that as regards the calcium content the soils of any one type are closely similar to one another, or that one type has a higher or lower lime content than another.

TABLE 22—CALCIUM AS CaO

(Surface horizons only)

Diablo Clay Adobe			Altamont Clay Loam			Hanford Fine Sandy Loam		
	%	%		%	%		%	%
1-A	1.86		3-A	5.64		14-A	2.91	
	1.80	1.83		.....	5.64		2.99	2.95
2-A	2.12		4-A	0.92		15-A	2.98	
	1.98	2.05		0.88	0.90		3.22	3.10
5-A	0.56		7-A	0.89		16-A	2.48	
	0.17	0.36		0.67	0.78		2.65	2.56
6-A	0.67		Average	2.44		19-A	3.28	
	.....	0.67					3.17	3.22
Average	1.23					20-A	2.69	
							2.73	2.71
						22-A	3.80	
							3.92	3.86
						23-A	2.88	
							3.00	2.94
						24-A	3.88	
							4.00	3.94
						25-A	4.58	
							4.80	4.69
						Average	3.33	

TABLE 23—CALCIUM AS CaO

San Joaquin Sandy Loam

Sample	Horizon					
	A %	Average %	B %	Average %	C %	Average %
10	0.67		0.82		1.11	
	0.62	0.64	1.03	0.92	1.12	1.11
11	1.94		1.62		1.65	
	1.26	1.60	1.70	1.66	1.55	1.60
12	3.12		2.21		2.61	
	3.50	3.31	.....	2.21	3.01	2.81
13	2.83		2.38		2.46	
	3.13	2.98	2.46	2.42	2.79	2.62
17	1.83		1.92		No sample	
	2.08	1.95	2.08	2.00		
18	1.40		1.00		1.48	
	1.34	1.37	1.45	1.22	1.42	1.45
21	0.91		0.89		0.85	
	0.84	0.87	0.83	0.86	0.89	0.87
26	0.48		0.13		0.17	
	0.47	0.47	0.10	0.11	0.17	0.17
Average		1.65		1.42		1.52

MAGNESIUM AS MgO

Diablo clay adobe.—This type shows a moderate variability in the magnesium content, with from 1.13% MgO to 3.26%, averaging 2.09%. The largest quantity is three times that of the smallest (tables 24, 25, figs. 15–18).

Altamont clay loam.—Within the three samples of this type the range in the MgO content is very great, from 0.07% to 1.90%, with the average of 1.05%. The largest is twenty-seven times that of the smallest.

San Joaquín sandy loam.—The total MgO in the samples of the type is low, considering that some soils reported by Hilgard contain from 1% to 3% magnesia by the acid digestion. The variation within the A horizon is from 0.34% to 0.90%, with the average of 0.62%, i.e., the largest is three times the smallest. The quantities in the B horizon are somewhat erratic as compared with those of the surface, yet in both the B and C horizons the results approach those of the surface sufficiently to give a rough parallelism. The greater amount of clay and fine silts with the increase of depth gives, as one would expect, an increase of magnesium. The average MgO content in the B horizon is 0.81%, and in the C horizon 1.05%.

TABLE 24—MAGNESIUM AS MgO
(Surface horizon only)

Diablo Clay Adobe			Altamont Clay Loam			Hanford Fine Sandy Loam		
	%	%		%	%		%	%
1-A	1.64		3-A	1.85		14-A	2.49	
	2.20	1.92		1.95	1.90		2.49	2.49
2-A	2.16		4-A	1.21		15-A	0.93	
	1.95	2.05		1.17	1.19		1.02	0.97
5-A	1.23		7-A	0.09		16-A	1.10	
	1.03	1.13		0.05	0.07		0.99	1.04
6-A	3.62		Average	1.05		19-A	2.11	
	2.90	3.26					1.99	2.05
Average	2.09					20-A	1.77	
							1.92	1.84
						22-A	2.44	
							2.71	2.57
						23-A	1.94	
							1.70	1.82
						24-A	2.14	
							2.13	2.13
						25-A	2.31	
							2.40	2.35
						Average	1.92	

Hanford fine sandy loam.—The MgO content of the surface soil varies from 0.97% to 2.57%, averaging 1.92%. The relative variation within this type is about that of the Diablo and San Joaquin types.

Comparing the average amounts of magnesium oxide in the surface horizon of the several types, we find the San Joaquin with 0.56%, the Altamont with 1.05%, the Hanford with 1.93%, and the Diablo with 2.09%. The averages do not signify much, however, because of the wide ranges within the types. Therefore as regards magnesium the types are neither distinct nor are the soils within the type closely similar.

TABLE 25—MAGNESIUM AS MgO

San Joaquin Sandy Loam

Sample	Horizon					
	A %	Average %	B %	Average %	C %	Average %
10-A	0.31		0.33		0.53	
	0.30	0.30	0.45	0.39	0.53	0.53
11-A	0.79		1.21		1.48	
	0.44	0.61	1.22	1.21	1.25	1.36
12-A	0.83		0.79		1.57	
	0.79	0.81	.....	0.79	1.62	1.59
13-A	0.90		1.70		1.67	
	0.80	0.85	1.63	1.66	1.82	1.74
17-A	0.53		0.51		No sample	
	0.74	0.63	0.77	0.64		
18-A	0.50		0.40		0.64	
	0.48	0.49	0.69	0.54	0.75	0.69
21-A	0.29		0.28		0.52	
	.....	0.29	0.31	0.29	0.56	0.54
26-A	0.50		0.52		0.52	
	0.52	0.51	0.44	0.48	0.53	0.52
Average		0.56		0.75		1.00

PHOSPHORUS AS P_2O_5

Diablo clay adobe.—The variations in the P_2O_5 content in the samples of this type are relatively small, from 0.092% to 0.162%, with 0.108% as the average (tables 26, 27, figs. 11-14).

Altamont clay loam.—The range of variation in the amount of P_2O_5 is large, from 0.031% to 0.265%, the largest quantity being eight times the smallest. The average is 0.132%.

San Joaquin sandy loam.—The variations in the P_2O_5 content of the surface soil are from 0.039% to 0.11%, with the average 0.068%. The curve is fairly regular. The subsoils follow the surface in a general way. The B horizon samples vary in the phosphoric acid content between 0.028% and 0.156%, and average 0.069%. The C samples vary between 0.03% and 0.109%, and average 0.067%. The averages of the three horizons are seen to be almost identical. No particular significance can be attached to the minor variations.

Hanford fine sandy loam.—The P_2O_5 content in the samples of this type is very variable, from 0.195% to 0.819%, with the average of 0.363%. The average of the San Joaquin sandy loam samples is 0.069%, of the Diablo clay adobe 0.108%, of the Altamont clay loam 0.132%, and of the Hanford fine sandy loam 0.363%. Except between the Diablo and Altamont types these averages would show considerable differences, if it were not that the samples frequently show such wide departures from the averages. The ranges of the several types frequently overlap.

TABLE 26—PHOSPHORUS AS P_2O_5
(Surface horizon only)

Diablo Clay Adobe			Altamont Clay Loam			Hanford Fine Sandy Loam		
	%	%		%	%		%	%
1-A	0.088		3-A	0.278		14-A	0.373	
	0.096	0.092		0.252	0.265		0.292	0.333
2-A	0.064		4-A	0.081		15-A	0.287	
	0.078	0.071		0.117	0.099		0.260	0.273
5-A	0.137		7-A	0.034		16-A	0.260	
	0.082	0.109		0.028	0.031		0.277	0.268
6-A	0.143		Average	0.132		19-A	0.303	
	0.181	0.162					0.272	0.287
Average		0.108				20-A	0.190	
							0.200	0.195
						22-A	0.397	
							0.401	0.399
						23-A	0.242	
							0.270	0.256
						24-A	0.421	
							0.454	0.437
						25-A	0.879	
							0.759	0.819
						Average		0.363

TABLE 27—PHOSPHORUS AS P_2O_5 *San Joaquin Sandy Loam*

Sample	Horizon					
	A %	Average %	B %	Average %	C %	Average %
10	0.118		0.060		0.047	
	0.102	0.110	0.068	0.064	0.057	0.052
11	0.049		0.047		0.049	
	0.060	0.054	0.046	0.046	0.028	0.028
12	0.057		0.028		0.064	
	0.071	0.064	.....	0.028	0.095	0.078
13	0.049		0.037		0.036	
	0.064	0.056	0.038	0.039	0.024	0.030
17	0.036		0.041		No sample	
	0.042	0.039	0.082	0.061		
18	0.043		0.097		0.086	
	0.055	0.049	0.074	0.085	.....	0.086
21	0.069		0.088		0.094	
	0.068	0.068	0.066	0.077	0.062	0.078
26	0.117		0.130		0.120	
	0.092	0.104	0.182	0.156	0.098	0.109
Average		0.068		0.069		0.067

POTASSIUM AS K_2O

Diablo clay adobe.—There is a moderate range in the variation in the amount of K_2O within this type, the lowest amount being 1.48% and the highest 2.06%, the four samples averaging 1.71% (table 28, figs. 15-18).

Altamont clay loam.—A greater variation, from 1.09% to 2.14%, of K_2O , occurs in the three samples of this type. The average is 1.74%.

San Joaquin sandy loam.—This type shows the greatest variation, from 0.98% to 2.84%. But even so, the the largest quantity of K_2O is less than three times the smallest. 1.88% K_2O is the average of the eight samples. Nos. 11 and 12 of this type show the smallest amounts of K_2O of any of the twenty-four samples.

Hanford fine sandy loam.—The variation in the K_2O content of the samples of this type is not great—from 1.73% to 3.16%, with the average of 2.33%. This is the highest average, as the Diablo clay adobe samples show 1.71%, the Altamont clay loam 1.74%, and the San Joaquin sandy loam 1.88%. Because of the considerable range in the amounts of K_2O for the several samples of a type, and because of the many overlappings of the values for one type over another, the averages do not mean much and do not show the soils within a type to be closely similar, nor do they show the types distinct.

TABLE 28—POTASSIUM AS K₂O

(J. Lawrence Smith Method)

Diablo Clay Adobe			Altamont Clay Loam			San Joaquin Sandy Loam			Hanford Fine Sandy Loam		
No.	%	Average %	No.	%	Average %	No.	%	Average %	No.	%	Average %
1-A	1.68		3-A	1.06		14-A	1.79		10-A	2.14	
	1.67	1.67		1.13	1.09		1.67	1.73		2.12	2.13
2-A	1.62		4-A	1.92		15-A	2.54		11-A	0.99	
	1.69	1.65		2.36	2.14		2.62	2.58		0.98	0.98
5-A	1.45		7-A	1.90		16-A	2.42		12-A	1.03	
	1.51	1.48		2.10	2.00		2.46	2.44		1.02	1.02
6-A	2.01		Average	1.74		19-A	2.10		13-A	1.50	
	2.12	2.06					2.03	2.06		.....	1.50
Average	1.71					20-A	2.00		17-A	2.40	
							1.81	1.90		2.24	2.32
						22-A	2.68		18-A	2.07	
							2.62	2.65		2.28	2.17
						23-A	3.10		21-A	2.81	
							3.23	3.16		2.88	2.84
						24-A	2.29		26-A	2.04	
							2.21	2.25		2.09	2.06
						25-A	2.18		Average	1.88	
							2.21	2.19			
						Average	2.33				

BACTERIOLOGICAL DATA

The bacteriological work was not entirely satisfactory, partly because the conditions in one of the incubators were not all that might be desired, and partly because of the refractory physical properties of some of the soils. The Diablo and Altamont types, in all three horizons, were very heavy and hard to mix and keep in even fair physical condition. The San Joaquin soils were predominantly of a heavy texture in the B and C horizons, while the surface horizon was light and the crumb structure was entirely lost if even a *small* excess of water was added to the culture.

AMMONIFICATION

There are very marked differences between the various types in this determination, though the samples in a given type vary among themselves to a large extent.

Diablo clay adobe.—The highest ammonia production was about three times the lowest, 7.7 mg. and 26 mg. In both this type and the following, the B and C horizons follow the surface horizon quite

Fig. 19-A.

Fig. 19A. Graph showing ammonification in the four samples of Diablo clay adobe. The quantities are expressed in terms of nitrogen produced per 100 grams of soil with 2% of dried blood.

Fig. 19-B

Fig. 19B. Graph showing nitrogen fixation in the three horizons of the four samples of Diablo clay adobe. The quantities are expressed in terms of milligrams of nitrogen fixed per gram of mannite in 50 grams of soil.

closely from sample to sample (table 28 and fig. 19A). This may be due to the textures, which are quite similar throughout the soil column. The averages for the three horizons were: A, 18.6 mg.; B, 12.6 mg.; and C, 8.9 mg.

Fig. 20A. Graph showing ammonification in the three horizons of the three samples of Altamont clay loam.

Fig. 20B. Graph showing nitrogen fixation in milligrams in the three horizons of the three samples of Altamont clay loam.

Altamont clay loam.—As regards horizon A the amount of ammonia produced in one soil is three times that in the lowest, 10 mg. nitrogen and 33 mg. nitrogen as ammonia, with 8.9 mg. as the average (table 30 and fig. 20A). The amount of nitrogen as ammonia produced in the B horizon averaged 12.6 mg., in the C horizon 8.9 mg.

San Joaquin sandy loam.—The amount of ammonia produced in the A horizon varied between 30.4 mg. of nitrogen and 57.1 mg., the average was 40.2 mg. (table 31 and fig. 21A). The production of ammonia, in milligrams of nitrogen, by the B samples varied between 4.5 mg. and 38.1 mg., with 20 mg. as the average. In the C samples the variation was nearly as great, between 5.7 mg. and 32 mg., with the average of 20.9 mg. Thus there are notable variations among the

Fig. 21A. Graph showing ammonification in the three horizons of the eight samples of San Joaquin sandy loam.

samples of this type, the proportional variation being very great, considering the three horizons. Possibly the reason that the B and C horizons are so divergent from the surface is that there is a very marked variation in the texture between the surface horizon and those below the surface.

Hanford fine sandy loam.—The variation is large here also (table 32, fig. 22A), the largest quantity of ammonia produced in the surface soil is twice that of the smallest production, 72 mg. and 35 mg. The subsoil variations, in a general way, parallel those of the surface. The average production of ammonia in the three horizons is as fol-

lows: A, 56.9 mg. nitrogen; B, 46.3 mg. nitrogen; and C, 38.7 mg. nitrogen. In attempting to correlate the variations in ammonifying powers with the known variations of the soils, or with the known histories of the soils, there seem to be no relations of significance.

The Altamont and Diablo types are about alike in their low ammonifying power. The Hanford and San Joaquin are both higher and nearer to each other than to the two heavy types, yet the Hanford is noticeably higher than the San Joaquin. This is as one would expect, from a knowledge of the soils in the field. Considering the types as a whole, as represented by the A horizon, there are more marked variations between the types than between the samples of a given type though the variations within a given type are very large.

TABLE 29—AMMONIFICATION

*Diablo Clay Adobe*Milligrams N as NH_3 Produced

Sample	A			B			C		
	Cultures	Checks average	Increase over checks	Cultures	Checks average	Increase over checks	Cultures	Checks average	Increase over checks
1	31.48			28.58			24.24		
	40.32	2.52	33.38	22.98	2.28	23.50	14.99	2.42	17.19
2	19.81			9.45			8.41		
	17.07	1.68	16.76	9.84	1.91	7.73	9.95	1.05	8.13
5	15.90			11.55			No sample		
	.....	1.75	14.15	12.54	1.54	10.50			
6	12.33			7.76			12.33		
	.....	2.11	10.22	13.55	2.07	8.58	12.33	2.03	10.30
Average			18.63			12.58			11.87

TABLE 30—AMMONIFICATION

*Altamont Clay Loam*Milligrams N as NH_3 Produced

Sample	A			B			C		
	Cultures	Checks average	Increase over checks	Cultures	Checks average	Increase over checks	Cultures	Checks average	Increase over checks
3	8.14			6.97			5.89		
	10.58	1.68	7.68	7.15	1.40	5.16	4.91	1.54	3.86
4	19.75			6.59			5.41		
	19.12	2.66	16.77	6.67	1.36	5.27	5.12	1.19	4.07
7	28.66			19.66			8.00		
	27.53	2.03	26.06	16.25	1.75	16.20	12.37	1.33	8.95
Average			16.84			8.88			5.63

TABLE 31—AMMONIFICATION

*San Joaquin Sandy Loam*Milligrams N as NH_3 Produced

Sample	A			B			C		
	Cultures	Checks average	Increase over checks	Cultures	Checks average	Increase over checks	Cultures	Checks average	Increase over checks
10	54.24			42.63			28.89		
	41.95	1.72	46.73	36.11	1.28	38.09	38.25	1.59	31.98
11	44.47			7.47			6.05		
	73.23	1.70	57.15	12.52	1.81	8.18	6.78	1.68	4.78
12	44.48			18.73			10.91		
	40.07	1.56	40.71	21.81	1.50	18.77	6.11	1.14	7.87
13	41.66			5.41			3.80		
	45.94	1.30	42.50	5.36	0.86	4.52	15.17	0.88	8.60
17	30.19			27.59			No sample		
	33.88	1.66	30.37	20.68	1.51	22.62			
18	35.04			30.56			21.96		
	35.24	1.48	33.66	22.81	1.30	25.38	16.92	1.47	17.97
21	34.44			37.41			25.72		
	30.89	1.48	31.18	37.74	1.38	36.19	29.66	1.42	26.27
26	40.81			7.50			9.08		
	.....	1.64	39.17	8.41	1.44	6.51	5.43	1.54	5.71
Average			40.18			20.03			12.89

TABLE 32—AMMONIFICATION

*Hanford Fine Sandy Loam*Milligrams N as NH_3 Produced

Sample	A			B			C		
	Cultures	Checks average	Increase over checks	Cultures	Checks average Horizons	Increase over checks	Cultures	Checks average	Increase over checks
14	37.35			27.96			14.39		
	43.57	1.78	38.68	48.46	1.46	36.75	41.70	1.24	26.80
15	33.11			45.68			59.90		
	41.75	1.75	35.68	48.38	1.70	45.33	52.59	1.62	54.62
16	56.59			44.08			44.58		
	56.77	1.83	54.85	42.10	1.61	41.48	52.10	1.69	46.65
19	52.92			46.70			24.56		
	51.85	1.47	50.91	38.92	1.13	41.68	28.12	1.24	25.10
20	72.49			45.49			22.05		
	74.21	1.36	71.99	38.52	1.03	40.97	30.35	1.00	25.20
22	64.92			57.44			46.08		
	67.56	1.75	64.49	55.34	1.51	54.88	47.55	1.60	45.21
23	71.56			50.84			35.15		
	68.66	1.61	68.50	43.01	1.37	45.55	35.23	1.35	33.84
24	65.02			50.09			37.56		
	59.51	1.50	60.76	46.54	1.32	46.99	40.21	1.33	37.55
25	68.20			69.29			61.01		
	67.29	1.43	66.31	60.03	1.25	63.41	47.70	1.22	53.13
Average			56.91			46.34			38.67

NITROGEN FIXATION²⁸

Diablo clay adobe.—This type shows the highest quantity of nitrogen fixed, 9.6 mg., with the subsoil quantities, much lower than the surface. The variation within the type is seen to be the largest of that in any of the types.

Altamont clay loam.—The surface samples have 1.0, 4.7, and 9.1 mg. nitrogen (table 34 and fig. 20B). The soils shows a wide divergence between the surface samples and between the surface and subsoils. This is to be expected in the heavier soils.

Fig. 21B. Graph showing nitrogen fixation in the three horizons of the eight samples of San Joaquin sandy loam.

San Joaquin sandy loam.—The quantity fixed in the A horizon (table 35 and fig. 21B) is small and quite variable. It is between nothing and 5.5 mg., with the average of 1.9 mg. Instead of nitrogen fixation denitrification took place in a number of cases, especially in horizon C. Considering the wide variation in textures of the horizons, it is rather odd that there should not be a greater variation between the soils from the various depths.

Hanford fine sandy loam.—The amount of nitrogen fixed by the surface soil (table 36, and fig. 22B) averages much higher, 5.7 mg., than that in the San Joaquin sandy loam, though the range of variation is about the same. It is noticeable that the amounts of nitrogen fixed by the B and C horizons of the soils nos. 14 and 19 are much

²⁸ All of the figures on nitrogen fixation refer to the milligrams of nitrogen fixed per gram of mannite in 50 grams of soil (table 33 and figs. 9-13).

less (even to denitrification) absolutely and relatively as compared with the surface horizons, than the amount fixed by the B and C horizons of the soils nos. 20 to 25 inclusive.

Comparing the nitrogen fixation of the various types, there seem to be no characteristic differences between the heavy Altamont and Diablo types, while the lighter Hanford and San Joaquin types are considerably different from each other. As a whole there is but a fair degree of similarity between the samples of a given type. The degree of variation within types is large.

TABLE 33—NITROGEN FIXATION

Diablo Clay Adobe

Milligrams N per gram of mannite

Sample	A			B			C		
	Cultures	Checks average	Increase over checks	Cultures	Checks average	Increase over checks	Cultures	Checks average	Increase over checks
1	60.25			31.52			22.77		
	63.40	52.22	9.60	29.56	34.67	-4.13	24.87	28.61	-4.79
2	55.34			32.92			30.47		
	49.39	45.88	6.48	38.18	33.80	1.75	32.22	29.77	1.57
5	48.68			35.73			No sample		
	48.68	41.92	6.76	37.12	32.39	4.03			
6	45.88			39.64			35.02		
	46.86	58.49	-12.12	42.72	50.77	-9.59	39.01	39.05	-2.03
Average			4.71			1.44			0.52

TABLE 34—NITROGEN FIXATION

Altamont Clay Loam

Milligrams N fixed per gram of mannite

Sample	A			B			C		
	Cultures	Checks average	Increase over checks	Cultures	Checks average	Increase over checks	Cultures	Checks average	Increase over checks
3	71.26			49.04			37.13		
	70.40	61.71	9.12	51.84	43.78	6.66	38.51	33.76	4.06
4	60.25			28.02			20.31		
	52.19	51.49	4.73	27.32	26.48	1.19	21.01	20.48	0.18
7	52.95			37.75			30.81		
	53.44	52.12	1.08	37.40	36.60	1.00	27.18	29.94	-0.94
Average			4.98			2.95			1.41

Fig. 22A. Graph showing ammonification in the three horizons of the nine samples of Hanford fine sandy loam.

Fig. 22B. Graph showing nitrogen fixation in the three horizons of the nine samples of Hanford fine sandy loam.

TABLE 35—NITROGEN FIXATION

San Joaquin Sandy Loam

Milligrams N fixed per gram of mannite

Sample	A			B			C		
	Cultures	Checks average	Increase over checks	Cultures	Checks average	Increase over checks	Cultures	Checks average	Increase over checks
10	25.01			17.16			15.83		
	23.47	18.73	5.51	16.67	13.59	3.32	18.14	10.33	6.65
11	27.25			22.91			21.72		
	31.87	25.15	4.41	22.84	21.78	1.09	22.00	19.43	2.43
12	25.85			20.17			18.98		
	23.82	23.26	1.57	17.09	16.56	2.07	20.10	20.41	-0.87
13	22.77			18.49			13.31		
	21.58	20.00	2.17	17.86	20.21	-2.04	14.50	16.35	-2.45
17	13.52			9.46			No sample		
	13.45			10.23					
18	15.55			8.76			9.18		
	13.24	13.73	0.66	8.20	8.09	0.39	11.42	9.74	0.56
21	14.85			7.98			6.58		
	16.11	14.50	0.98	6.44	5.96	1.25	7.28	7.01	-0.07
26	19.54			12.61			7.14		
	19.34	20.34	-0.94	12.82	13.34	-0.72	7.36	8.24	-0.99
Average			1.91			1.09			1.20

TABLE 36—NITROGEN FIXATION

Hanford Fine Sandy Loam

Milligrams N fixed per gram of mannite

Sample	A			B			C		
	Cultures	Checks average	Increase over checks	Cultures	Checks average	Increase over checks	Cultures	Checks average	Increase over checks
14	71.52			41.61			31.10		
	63.05	59.61	7.67	41.69	41.01	0.64	30.19	29.07	1.57
15	38.18			22.07			12.40		
	29.56	26.55	7.32	21.09	20.12	1.46	14.08	13.87	-0.63
16	30.33			16.46			9.67		
	32.92	27.84	3.78	16.04	14.85	1.40	8.97	10.61	-1.29
19	25.56			14.43			11.77		
	26.41	22.49	4.49	13.59	12.29	1.72	12.33	11.80	-0.25
20	38.04			22.84			17.09		
	38.11	29.66	8.41	23.61	16.39	6.83	20.60	11.52	7.32
22	35.59			22.20			17.30		
	31.80	29.17	4.52	23.40	17.23	5.57	16.46	11.87	5.01
23	38.95			19.19			11.90		
	43.57	36.10	5.16	20.25	14.57	5.15	11.98	8.90	3.04
24	28.79			19.89			18.52		
	34.61	25.67	6.03	21.52	16.95	3.75	17.51	13.91	4.11
25	26.55			17.86			15.55		
	26.41	22.70	3.78	17.93	15.51	2.38	13.87	11.31	3.41
Average			5.69			3.21			2.27

NITRIFICATION²⁹

The most noticeable thing about the nitrification results is the very wide range of variation in the various representatives of the Hanford fine sandy loam as compared with the quite uniform and consistent results obtained with the other types.

Diablo clay adobe.—The percentage of nitrogen nitrified (table 37, 38, and fig. 23) is uniformly low. The B samples showed a less vigorous nitrifying flora (except in the case of no. 6) than the surface ones. Dried blood in the quantities used seems to depress the

Fig. 23. Graph showing the percentages of nitrogen in various nitrogen containing materials nitrified in the four samples of the Diablo clay adobe.

normal activity (A horizon average 0.81%), while the $(\text{NH}_4)_2\text{SO}_4$ (A horizon average 3.03%) and the cottonseed meal (A horizon average 2.91%), as compared with the incubated control tend to increase the percentage of nitrogen nitrified. It should be kept in mind that an absolute increase in the nitrogen content may accompany a decrease in the percentage, due to the greatly increased amount of nitrogen present after the addition of a nitrogenous substance. The variation of the samples within this type is very moderate as compared with the San Joaquin and Hanford types.

²⁹ The figures used in the discussion shows the percentages of the nitrogen in the cultures which were nitrified. There are two tables for the samples of each type. The percentages of nitrogen nitrified are rearranged in a second table for greater ease in comparing results.

Altamont clay loam.—The percentages of nitrogen nitrified (tables 39 and 40, fig. 24) are as a whole lower than in the Diablo soils. A similar relative effect of the several nitrogenous materials is seen, for $(\text{NH}_4)_2\text{SO}_4$ is first, cottonseed meal, second, the soil's own nitrogen third, and dried blood fourth in the percentages of nitrates produced. As in the Diablo soils the variation is not great from soil to soil.

San Joaquin sandy loam.—A wide range of variation (tables 41, 42, and fig. 25), from 1.2% to 4.5%, is found in the incubated control, possibly due, in part, to the considerable variations in the physical nature of the samples. The relative action of the nitrogenous ma-

Fig. 24. Graph showing the percentages of nitrogen in various nitrogen containing materials nitrified in the three samples of the Altamont clay loam.

terials in the soils of the San Joaquin samples as compared with that in the Diablo and Altamont soils is well shown by the following averages of the A horizon: dried blood had 0.02%, cottonseed meal had 0.33%, and ammonium sulfate had 0.56% of the nitrogen nitrified, while the incubated control had 2.47% nitrified. The soils are normally low in nitrogen, and this, together with the poor physical condition, made an unfavorable medium for any bacterial activity. This applies especially to horizons B and C.

Hanford fine sandy loam.—This is by far the most inexplicable set of results in the nitrification studies (tables 43, 44, and fig. 26). The physical nature of this type is admirably suited for bacteriological tumbler cultures, the soil being friable, not puddling readily, and while in the incubator may be kept at the approximately optimum moisture content with little difficulty. This property is fairly con-

stant throughout all the samples (except no. 14) and cannot well be supposed to affect the results greatly. No. 14 has a low nitrifying power throughout, but it is not representative of the type, for it is heavier in texture than the rest. Moreover, it had been submerged by river overflows shortly before the collection of the sample. One would expect these factors to influence the numbers and the activity of the bacterial flora. There is but little similarity in the way the different samples of the A or B horizons behave toward any given

Fig. 25. Graph showing the percentages of nitrogen in various nitrogen containing materials nitrified in the eight samples of the San Joaquin sandy loam.

nitrogen containing material. Variations from 1% to 50%, from 0% to 14%, from 4.5% to 8%, or from 15% to 15.5% from soil to soil, without regularity, give slight basis for generalizations. The average effect of the A horizon samples of the Hanford fine sandy loam as regards the several nitrogenous materials is as follows: dried blood, 5.62%; cottonseed meal, 13.72%; ammonium sulfate, 3.29%; incubated control, 1.55%. In a general way there is a similarity between the effects of a given nitrogen containing material on the surface sample, and on the B horizon. This should be so, since these soils are very deep and uniform in texture. However, in the C horizon there were still greater decreases in the bacterial activity.

As regards nitrification in general there is difficulty in showing any greater resemblance between the samples of a type than there is from type to type. In certain features, however, the types are somewhat distinct: (1) The relation of the nitrification of the soil's own nitrogen to the soil's action upon added nitrogen is rather distinct for the types. The normal soil in the San Joaquin type gave a much larger per cent of nitrogen than did the soil plus the added nitrogen containing materials. In the Diablo type (fig. 25) the normal soil was about midway in its production as compared with the soils to which the nitrogenous materials were added. In the Hanford fine sandy loam the normal soils gave a much lower percentage nitrification than in the greater number of instances where the soils were treated with nitrogenous materials. (2) The relative nitrification of the various nitrogenous materials is somewhat distinct for the types. The Diablo, Altamont, and San Joaquin show the ammonium sulfate first, with the cottonseed meal second, and the dried blood third. The Hanford type shows cottonseed meal first, with dried blood second and ammonium sulfate third.

TABLE 37—NITRIFICATION

Diablo Clay Adobe

Sample	Soil nitrogen			Soil nitrogen and ammonium sulfate			Soil nitrogen and dried blood			Soil nitrogen and cottonseed meal		
	Nitrate produced, mg.	Total N present in soil, mg.	Nitrogen nitrified, %	Nitrate produced, mg.	Total N present in soil, mg.	Nitrogen nitrified, %	Nitrate produced, mg.	Total N present in soil, mg.	Nitrogen nitrified, %	Nitrate produced, mg.	Total N present in soil, mg.	Nitrogen nitrified, %
1-A	0.90	104.43	0.86	5.35	146.82	3.65	2.20	347.22	0.63	5.00	198.42	2.50
1-B	0.28	93.34	0.30	0.77	135.74	0.57	Tr.	336.14	.....	Tr.	187.34	.....
1-C	0.19	57.22	0.33	0.25	99.62	0.25	0.07	300.02	0.02	0.16	151.22	.....
2-A	0.47	117.6	0.51	3.47	134.16	2.58	4.07	334.56	1.22	6.82	185.76	3.77
2-B	0.33	67.60	0.49	1.17	110.00	1.06	0.08	310.40	.....	0.19	161.60	0.12
2-C	0.59	59.54	.....	0.29	101.94	.....	0.80	302.34	.....	0.80	153.54	.....
5-A	0.47	83.82	0.56	3.81	126.22	3.02	1.66	326.62	0.51	3.76	177.82	2.12
5-B	0.36	64.78	0.56	0.42	107.18	0.39	0.19	307.58	0.06	0.97	158.78	0.61
6-A	0.59	116.58	0.51	4.58	158.98	2.88	3.13	359.38	0.87	6.88	210.58	3.26
6-B	1.65	101.54	1.63	3.00	143.94	2.08	1.19	344.34	0.35	4.55	195.54	2.32
6-C	0.96	78.10	1.23	1.01	120.50	0.84	0.37	320.90	0.01	0.47	172.10	0.27

Fig. 26. Graph showing the percentages of nitrogen in various nitrogen containing materials nitrified in the nine samples of the Hanford fine sandy loam.

TABLE 38—NITRIFICATION—PERCENTAGES OF NITROGEN NITRIFIED

Diablo Clay Adobe

Sample	Soil nitrogen			Soil nitrogen and ammonium sulfate			Soil nitrogen and dried blood			Soil nitrogen cottonseed meal		
	A	B	C	A	B	C	A	B	C	A	B	C
1	0.86	0.30	0.33	3.65	0.57	0.25	0.63	.....	0.02	2.50	.....	.....
2	0.51	0.49	.....	2.58	1.06	.....	1.22	.....	.....	3.77	0.12	.....
5	0.56	0.56	.....	3.02	0.39	.....	0.51	0.06	.....	2.12	0.61	.....
6	0.51	1.63	1.23	2.88	2.08	0.84	0.87	0.35	0.01	3.26	2.32	0.27
Average	0.61	0.74	0.52	3.03	1.02	0.36	0.81	0.10	0.01	2.91	0.76	0.09

TABLE 39—NITRIFICATION

Altamont Clay Loam

Sample	Soil nitrogen			Soil nitrogen and ammonium sulfate			Soil nitrogen and dried blood			Soil nitrogen and cottonseed meal		
	Nitrate produced, mg.	Total N present in soil, mg.	Nitrogen nitrified, %	Nitrate produced, mg.	Total N present in soil, mg.	Nitrogen nitrified, %	Nitrate produced, mg.	Total N present in soil, mg.	Nitrogen nitrified, %	Nitrate produced, mg.	Total N present in soil, mg.	Nitrogen nitrified, %
3-A	0.60	123.42	0.49	4.12	165.82	2.49	1.17	366.22	0.32	3.57	217.42	1.64
3-B	0.04	87.56	0.05	0.39	129.96	0.32	0.18	330.36	.....	0.03	181.56	.....
3-C	0.27	67.52	0.40	0.20	109.92	0.18	0.10	310.32	.....	0.10	161.52	.....
4-A	1.30	102.58	1.27	2.95	144.98	2.05	2.34	345.38	0.68	4.83	196.58	2.46
4-B	0.45	52.96	0.85	.....	95.36	.....	0.10	295.76	.....	.....	146.96	.....
4-C	.....	40.96	.....	.....	83.36	.....	.....	283.76	.....	0.20	134.96	0.15
7-A	0.50	104.24	0.48	1.35	146.64	0.93	0.40	347.04	0.12	1.27	198.24	0.64
7-B	0.25	73.20	0.34	0.32	115.60	0.28	.....	316.00	.....	.....	167.20	.....
7-C	.....	59.88	.....	.....	102.28	.....	.....	302.68	.....	.....	153.88	.....

TABLE 40—NITRIFICATION—PERCENTAGES OF NITROGEN NITRIFIED

Altamont Clay Loam

Sample	Soil nitrogen			Soil nitrogen and ammonium sulfate			Soil nitrogen and dried blood			Soil nitrogen and cottonseed meal		
	A	B	C	A	B	C	A	B	C	A	B	C
3	0.49	0.05	0.40	2.49	0.32	0.18	0.32	.....	.....	1.64	.....	.....
4	1.27	0.85	.....	2.05	.....	.....	0.68	.....	.....	2.46	.....	0.15
7	0.48	0.34	.....	0.93	0.28	.....	0.12	.....	.....	0.64	.....	.....
Average	0.75	0.41	0.13	1.82	0.20	0.06	0.37	.....	.....	1.58	.....	0.05

TABLE 41—NITRIFICATION

San Joaquin Sandy Loam

Sample	Soil nitrogen			Soil nitrogen and ammonium sulfate			Soil nitrogen and dried blood			Soil nitrogen and cottonseed meal		
	Nitrate produced, mg.	Total N present in soil, mg.	Nitrogen nitrified, %	Nitrate produced, mg.	Total N present in soil, mg.	Nitrogen nitrified, %	Nitrate produced, mg.	Total N present in soil, mg.	Nitrogen nitrified, %	Nitrate produced, mg.	Total N present in soil, mg.	Nitrogen nitrified, %
10-A	0.52	37.46	1.4	0.24	122.26	0.2	0.06	302.46	0.02	0.10	121.46	0.08
10-B	0.23	27.18	0.9	0.08	111.98	0.07	.....	292.18	.....	.....	111.18	.....
10-C	0.07	20.66	0.3	0.06	105.46	0.06	.....	285.66	.....	0.08	104.66	0.08
11-A	1.25	50.30	2.5	0.50	135.10	0.4	0.27	315.30	0.09	0.95	134.30	0.7
11-B	.....	41.56	.....	0.02	126.86	.....	0.08	306.56	0.03	0.02	125.56	.....
11-C	0.14	38.86	0.4	Tr.	123.66	.....	Tr.	303.86	.....	Tr.	122.86	.....
12-A	0.80	46.52	1.7	0.55	131.32	0.4	0.09	311.52	0.03	2.05	130.52	1.6
12-B	0.18	33.12	0.5	0.11	117.92	0.09	Tr.	298.12	.....	Tr.	117.12	.....
12-C	0.14	40.82	0.3	0.06	125.62	.....	0.06	305.82	.....	0.06	124.82	.....
13-A	0.49	40.00	1.2	0.50	124.80	0.5	0.07	305.00	0.02	0.10	124.00	0.08
13-B	0.06	40.41	.....	0.10	125.21	0.08	0.21	305.41	.....	0.69	124.41	.....
13-C	0.35	32.70	1.1	0.25	117.50	0.2	0.00	297.70	.....	0.96	116.70	.....
17-A	0.54	28.92	1.9	0.45	113.72	0.4	Tr.	293.92	.....	.....	112.92	.....
17-B	.....	18.42	.....	.....	103.22	.....	Tr.	283.42	.....	0.08	102.42	0.08
18-A	1.25	27.46	4.5	1.00	112.26	0.9	.....	292.46	.....	Tr.	111.46	.....
18-B	Tr.	16.18	.....	Tr.	100.98	.....	Tr.	281.18	.....	Tr.	100.18	.....
18-C	.....	19.48	.....	0.10	104.28	1.0	.....	284.48	.....	.....	103.48	.....
21-A	1.25	29.00	4.3	1.30	113.80	1.1	Tr.	294.00	.....	0.13	113.00	.....
21-B	.....	11.92	.....	.....	96.72	.....	.....	276.92	.....	.....	95.92	.....
21-C	0.01	14.02	.....	0.01	98.82	0.01	0.15	279.02	.....	0.15	98.02	.....
26-A	0.95	40.68	2.3	0.80	125.48	0.6	Tr.	305.68	.....	0.19	124.68	0.10
26-B	Tr.	26.28	.....	.....	111.48	.....	Tr.	291.68	.....	Tr.	110.68	.....
26-C	.....	16.48	.....	.....	101.28	.....	Tr.	281.48	.....	.....	100.48	.....

TABLE 42—NITRIFICATION—PERCENTAGES OF NITROGEN NITRIFIED

San Joaquin Sandy Loam

Sample	Soil nitrogen			Soil nitrogen and ammonium sulfate			Soil nitrogen and dried blood			Soil nitrogen and cottonseed meal		
	A	B	C	A	B	C	A	B	C	A	B	C
10	1.4	0.9	0.3	0.2	0.07	0.06	0.02	.....	.....	0.08	.....	0.08
11	2.5	.....	0.4	0.4	.....	.....	0.09	0.03	.....	0.7	.....	.....
12	1.7	0.5	0.3	0.4	0.09	.....	0.03	.....	.....	1.6	.....	.....
13	1.2	.....	1.1	0.5	0.08	0.20	0.02	.....	.....	0.08	.....	.....
17	1.9	.....	.....	0.4	.....	.....	.....	.....	.....	.....	0.08	.....
18	4.5	.....	.....	0.9	.....	1.00	.....	.....	.....	.....	.....	.....
21	4.3	.....	.....	1.1	.....	0.01	.....	.....	.....	0.10	.....	.....
26	2.3	.....	.....	0.6	.....	.....	.....	.....	.....	0.1	.....	.....
Average	2.47	0.17	0.3	0.56	0.03	0.18	0.02	.....	.....	0.33	0.01	0.01

TABLE 43—NITRIFICATION
Hanford Fine Sandy Loam

Sample	Soil nitrogen			Soil nitrogen and ammonium sulfate			Soil nitrogen and dried blood			Soil nitrogen and cottonseed meal		
	Nitrate produced, mg.	Total N present in soil, mg.	Nitrogen nitrified, %	Nitrate produced, mg.	Total N present in soil, mg.	Nitrogen nitrified, %	Nitrate produced, mg.	Total N present in soil, mg.	Nitrogen nitrified, %	Nitrate produced, mg.	Total N present in soil, mg.	Nitrogen nitrified, %
14-A	0.20	119.22	....	0.25	161.62	0.1	10.35	254.22	4.1	1.85	166.22	1.1
14-B	0.45	82.02	....	0.42	124.42	....	0.23	217.02	....	0.48	129.02	....
14-C	0.07	58.14	0.1	0.75	100.54	0.7	0.15	193.14	0.1	0.10	105.14	0.1
15-A	1.45	53.10	2.7	3.20	95.50	3.4	0.40	188.10	0.2	50.85	100.10	50.8
15-B	0.18	40.24	0.4	0.19	82.64	0.2	Tr.	175.24	....	1.42	87.24	1.6
15-C	0.03	27.74	0.1	0.01	70.14	...	Tr.	162.74	....	0.03	74.74	....
16-A	0.87	55.68	1.6	2.50	98.08	2.5	0.50	190.68	0.2	4.60	102.68	4.5
16-B	0.11	29.70	0.4	0.08	72.10	0.1	Tr.	164.70	....	3.70	76.70	4.8
16-C	0.03	21.22	0.1	Tr.	63.62	....	0.05	156.22	....	0.17	68.22	0.2
19-A	1.00	44.98	2.2	2.03	87.38	2.3	0.21	179.98	0.1	7.48	91.98	8.1
19-B	0.08	24.58	0.3	0.12	66.98	0.2	.....	159.58	....	0.20	71.58	0.3
19-C	0.16	23.60	0.7	0.15	66.00	0.2	Tr.	158.60	....	0.20	70.60	0.3
20-A	0.77	59.32	1.3	1.24	101.72	1.2	27.39	194.32	14.1	6.19	104.32	5.9
20-B	0.12	32.78	0.4	0.11	75.18	0.1	15.50	167.78	9.2	1.45	77.78	1.9
20-C	.....	23.04	....	.....	65.44	..	.....	158.04	....	0.07	68.04	0.1
22-A	0.83	58.34	1.4	6.48	100.74	6.4	2.68	193.34	1.4	13.58	103.34	13.1
22-B	0.27	34.46	0.8	0.26	76.86	0.3	0.04	169.46	0.02	1.91	79.46	2.4
22-C	0.85	23.74	3.6	5.40	66.14	8.2	0.52	158.74	0.3	2.50	68.74	3.6
23-A	1.45	72.20	2.0	8.95	114.6	7.8	37.25	207.20	17.9	18.25	117.20	15.5
23-B	0.75	29.14	2.6	8.90	71.54	12.5	0.47	164.14	0.3	2.65	74.14	3.6
23-C	0.32	17.80	1.8	12.40	60.20	20.6	0.02	152.80	0.01	1.30	62.80	2.1
24-A	0.80	51.34	1.6	4.10	93.74	4.4	22.35	186.34	11.9	14.35	96.34	14.9
24-B	0.03	33.90	0.1	0.36	76.30	0.5	0.46	168.90	0.3	5.91	78.90	7.5
24-C	0.33	27.82	1.1	0.33	70.22	0.5	0.63	162.82	0.4	0.73	72.82	1.0
25-A	0.56	45.40	1.2	1.30	87.80	1.5	1.30	180.40	0.7	8.65	90.40	9.6
25-B	0.32	31.01	1.0	0.32	73.41	0.4	Tr.	166.01	....	0.05	76.01	0.06
25-C	0.11	22.62	0.5	0.16	65.02	0.2	Tr.	157.62	....	Tr.	67.62	.....

TABLE 44—NITRIFICATION—PERCENTAGES OF NITROGEN NITRIFIED
Hanford Fine Sandy Loam

Sample	Soil nitrogen			Soil nitrogen and ammonium sulfate			Soil nitrogen and dried blood			Soil nitrogen and cottonseed meal		
	A	B	C	A	B	C	A	B	C	A	B	C
14	....	....	0.1	0.1	....	0.7	4.1	....	0.1	1.1	....	0.1
15	2.7	0.4	0.1	3.4	0.2	....	0.2	....	....	4.5	4.8	0.2
16	1.6	0.4	0.1	2.5	0.1	....	0.2	....	....	4.5	4.8	0.2
19	2.2	0.3	0.7	2.3	0.2	0.2	0.1	....	....	8.1	0.3	0.3
20	1.3	0.4	....	1.2	0.1	....	14.1	9.2	...	5.9	1.9	0.1
22	1.4	0.8	3.6	6.4	0.3	8.2	1.4	0.02	0.3	13.1	2.4	3.6
23	2.0	2.6	1.8	7.8	12.5	20.6	17.9	0.3	0.01	15.5	3.6	2.1
24	1.6	0.1	1.1	4.4	0.5	0.5	11.9	0.3	0.4	14.9	7.5	1.0
25	1.2	1.0	0.5	1.5	0.4	0.2	0.7	....	....	9.6	0.06	....
Average	1.55	0.66	0.88	3.29	1.59	3.38	5.62	1.09	0.09	13.72	2.55	0.82

GREENHOUSE DATA

There are objections to all greenhouse work due to somewhat unnatural conditions for the usual indicator crops, the lack of a normal water supply, the small amount of root space, etc. Crowding of the pots is also apt to cause variations. Even the slight change in the location of a pot on the bench will affect the growth of plants, as some of the elaborate precautions for moving the pots daily, and in a given order, testify. The outstanding advantage of greenhouse work is that with a given indicator crop a group of soils, or soil conditions, may be compared under very similar conditions.

In the present case, the leaks in the sash allowed rain water to fall into some of the pots to a considerable extent. The pots so affected showed a poorer growth in the cases of the heavy Altamont and Diablo samples, where the soil was readily compacted, while in the poor Hanford and San Joaquin soils the pots receiving leakage water showed markedly better growth.

To minimize such errors, as much as possible, triplicates were used, as above explained, besides repeating the series. In working out the final averages of the crop it was suggested that a selection be made of the crop dry weights, in case that there was a marked variation between the triplicates, using the two weights close together, and excluding the third if it were widely divergent. However, when one begins to select certain figures from a series, and bases comparisons upon these alone, there is apt to be the tendency to select those figures that will prove the point in question, unless there is some known disturbing factor causing the divergence and which warrants the exclusion of certain figures.

Other cases that are rather hard to deal with are those in which the number of plants reaching maturity was not up to the standard to which the series was thinned when the plants were young. This failure may have been due to poor germination, or to accidental destruction of the plants during growth. Sometimes less than the standard number of plants will give a much greater dry weight per plant than the normal number. It was not deemed advisable to use the weight per plant, but rather to use the total dry weight of the crop, and only consider of value the series in which the number of plants per pot was practically constant.

In the greenhouse work the Diablo clay adobe, the Altamont clay loam, and the Hanford fine sandy loam samples were compared by

two croppings, while one crop was grown on the San Joaquin sandy loam soils. The infertility of the San Joaquin soils, in some cases extreme, greatly retarded crop growth.

Diablo clay adobe. First crop.—Due to the presence of wild oat seed in all the four samples of this soil, and the inability to distinguish the young wild oat plants from the planted oats, wheat, or barley when thinning, the value of the results of the grain crops in this series is much decreased. The averages plotted include the total

Fig. 27. Graph showing the total dry matter produced by wheat, barley, oats, *Phaseolus*, bur clover, and oats and bur clover on the four samples of Diablo clay adobe. First crop.

crop, whether pure or with a greater or less quantity of the wild oats, though the number of plants harvested was usually six or less. Planting the oats and bur clover together was not a success. In three of the soils the crop of bur clover alone was greater than that of the six bur clover plants plus the six oat plants. Plate 44 shows how, in some cases, the oats dominated, and in others the bur clover was superior. On the soils of this type bur clover was the most satisfactory crop, while the white beans were the most unsatisfactory of all.

Comparing the total crops (see fig. 27 and tables 45-50), it will be seen that 1, 5, 2, 6 is the order for bur clover, soil no. 1 giving the

best crop and soil no. 6 the poorest, while nos. 5, 1, 2, 6 is the order for barley and wheat. Oats show nearly double the crop on soil 5 that it does on any of the other three soils. There is thus a general agreement between the indicators that the soils are not of the same productivity.

TABLE 45—DIABLO CLAY ADOBE, FIRST CROP

WHEAT

Planted, November 6, 1915. Harvested, July 10, 1916

Pot	No. plants	Straw		Grain		Total dry matter		Notes
		Weight	Average weight	Weight	Average weight	Weight	Average weight	
1-1	Wheat 2	3.65		0.25				
	Oats 4	2.15		0.69		6.74		
1-2	Wheat 0	.....		.....				
	Oats 6	4.05		2.47		6.51		
1-3	Wheat 1	1.83		.....				
	Oats 5	5.20	5.62	1.64	1.68	8.66	7.30	
2-1	Wheat 5	5.33		0.05				
	Oats 1	0.43		.....		5.81		
2-2	Wheat 4	3.53		0.03				
	Oats 2	0.69		0.04		4.31		
2-3	Wheat 3	2.55		.....				
	Oats 3	1.39	4.63	0.49	0.21	4.43	0.84	
5-1	Wheat 2	4.33		0.90				
	Oats 4	1.56		0.42		7.21		
5-2	Wheat 3	7.28		1.81				
	Oats 2	3.23		1.02		13.44		
5-3	Wheat 3	7.09		0.48				
	Oats 2	0.64	8.04	0.47	1.70	8.68	9.74	
6-1	Wheat 2	2.19		.....				
	Oats 4	1.03		.....		3.22		
6-2	Wheat 0	.....		.....				
	Oats 5	1.72		.....		1.72		
6-3	Wheat 2	2.31		.....				
	Oats 4	2.51	3.25	0.70	0.17	5.53	3.49	

TABLE 46—DIABLO CLAY ADOBE, FIRST CROP

BARLEY

Planted, November 6, 1915. Harvested, April 28, 1916

Pot	No. plants	Straw		Grain		Total dry matter		Notes
		Weight	Average weight	Weight	Average weight	Weight	Average weight	
1-1	6	5.19		1.06		6.25		
1-2	Barley 5	4.79		0.75				
	Oats 1	.....		.....		5.54		
1-3	Barley 4	5.75		1.34				
	Oats 2	.....	5.24	0.98	1.38	8.07	6.62	
2-1	6	5.12		1.05		6.17		
2-2	6	4.87		1.71		6.58		
2-3	Barley 5	2.78		0.49				
	Oats 1	0.69	4.49	0.23	1.16	4.19	5.65	
5-1	6	6.59		2.12		8.70		
5-2	Barley 5			3.01				
	Oats 1	2.56		0.25		3.25		
5-3	Barley 5			3.01				
	Oats 1	8.43	5.86	0.04	1.95	11.48	7.81	
6-1	6	4.62		1.26		5.88		
6-2	6	4.36		1.25		5.61		
6-3	Barley 5			0.33				
	Oats 1	3.49	4.16	0.24	1.02	4.06	5.18	

TABLE 47—DIABLO CLAY ADOBE, FIRST CROP

OATS

Planted, November 6, 1915. Harvested, May 8, 1916

Pot	No. plants	Straw		Grain		Total dry matter		Notes
		Weight	Average weight	Weight	Average weight	Weight	Average weight	
1-1	6	4.11		1.24		5.35		
1-2	6	6.56		2.59		9.15		
1-3	6	4.76	5.14	1.34	1.72	6.10	6.86	
2-1	6	4.36		1.10		5.46		
2-2	6	total only		total only		6.92		
2-3	6	6.66	5.51	2.06	1.58	8.72	7.03	
5-1	7	7.55		2.59		10.15		
5-2	6	10.66		4.38		15.04		One barley plant
5-3	6	10.10		3.12		13.22		
6-1	6	4.70		1.48		6.18		
6-2	6	6.81		1.42		8.22		
6-3	6	6.78		1.09		7.88		

TABLE 48—DIABLO CLAY ADOBE, FIRST CROP
BUR CLOVER
Planted, November 6, 1915. Harvested, May 8, 1916

Pot	No. plants	Straw		Grain		Total dry matter		Notes
		Weight	Average weight	Weight	Average weight	Weight	Average weight	
1-1	5	11.01		15.13		26.32		
1-2	4	9.07		14.15		23.22		
1-3	6	12.18	10.75	13.02	14.16	25.20	24.91	
2-1	6	8.26		9.89		18.16		
2-2	5	7.45		8.93		16.39		
2-3	6	7.97	7.89	8.02	8.98	15.99	16.84	
5-1	7	11.14		12.33		23.48		
5-2	8	10.67		13.05		23.72		
5-3	7	10.55	10.79	9.76	11.71	20.31	22.50	
6-1	6	7.96		8.73		16.69		
6-2	6	8.26		9.76		18.02		
6-3	6	6.87	7.69	6.04	8.18	12.91	15.87	

TABLE 49—DIABLO CLAY ADOBE, FIRST CROP
OATS AND BUR CLOVER
Planted, November 6, 1915. Harvested, May 8, 1916

Pot	No. plants	Straw		Grain		Total dry matter		Notes
		Weight	Average weight	Weight	Average weight	Weight	Average weight	
1-1	Clover 3	10.37		11.93		22.30		
	Oats 6	2.38		0.14		2.52		
1-2	Clover 6	8.19		9.28		17.47		
	Oats 6	3.48		0.70		4.16		
1-3	Clover 6	13.53		9.81		23.34		
	Oats 6	2.65	13.53	0.27	10.71	2.92	24.24	
2-1	Clover 6	2.13		2.57		4.70		
	Oats 6	5.77		1.81		7.58		
2-2	Clover 6	4.24		4.62		8.87		
	Oats 6	4.56		1.26		5.82		
2-3	Clover 6	3.43		4.51		7.94		
	Oats 6	3.20	7.75	0.46	5.08	3.66	12.85	
5-1	Clover 6	10.88		9.78		20.66		
	Oats 6	2.45		0.27		2.71		
5-2	Clover 5	10.52		9.32		19.84		
	Oats 6	2.19		0.51		2.79		
5-3	Clover 5	8.31		8.36		16.66		
	Oats 6	3.45	12.60	0.66	9.63	4.10	22.26	
6-1	Clover 6	8.90		9.56		18.46		
	Oats 6	3.10		0.35		3.45		
6-2	Clover 6	9.01		5.82		14.83		
	Oats 6	2.09		0.52		2.61		
6-3	Clover 6	6.51		10.45		16.97		
	Oats 5	2.33	10.65	0.47	9.06	2.80	19.71	

TABLE 50—DIABLO CLAY ADOBE, FIRST CROP

Phaseolus vulgaris

Planted, April 4, 1916. Harvested, October 7, 1916

Pot	No. plants	Straw		Grain		Total dry matter		Notes
		Weight	Average weight	Weight	Average weight	Weight	Average weight	
1-1	8	2.05		0.58		2.63		Growth poor and slow through-out
1-2	1	0.94		0.87		1.81		
1-3	12	2.86	1.95	1.37	0.94	4.23	2.89	
2-1	3	0.53		0.21		0.74		
2-2	10	0.83		.....		0.83		
2-3	17	1.26	0.87	0.11	0.10	1.37	0.98	
5-1	3	0.53		0.40		0.93		
5-2	2	0.46		0.41		0.87		
5-3	....	.....	0.33	.....	0.27	.....	0.60	
6-1	2	0.22		.....		0.22		
6-2	....	.....		.....		.....		
6-3	1	0.23	0.15	.....	.....	0.23	0.15	

Diablo clay adobe. Second crop.—The crops used in this planting were milo (two series, one following oats and bur clover, and the other following oats alone), cowpeas, millet, and soy beans. The crop was thinned as follows: milo to eight plants, millet to twelve, soy beans to six, and cowpeas to six. The total dry weight (tables 51-55) of the largest leguminous crop in this planting is about one-third of that of the bur clover in the first planting; though the grains are proportionately not nearly so much less than in the first crop. Soil no. 2 has the least pronounced adobe structure, but was the most easily puddled. The plants in one of the pots of soy beans of soil no. 2 were entirely killed by too much water.

Comparing the relative growth on the soils, the notes made while the crops were growing coincide very closely with the dry weights. As to the relative crop production (fig. 28), it can be said that soils nos. 1 and 5 produced larger crops than soils nos. 2 and 6. Thus the second crop results substantiate those of the first crop.

Fig. 28. Graph showing the total dry matter produced by milo (two series), millet, soy beans, and cowpeas on the four samples of Diablo clay adobe. Second crop.

Fig. 29. Graph showing the total dry matter produced by wheat, barley, oats, bur clover, *Phaseolus*, and oats and bur clover on the three samples of Altamont clay loam. First crop.

Fig. 30. Graph showing the total dry matter produced by milo (two series), cowpeas (two series), and soy beans (two series) on the three samples of Altamont clay loam. Second crop.

TABLE 51—DIABLO CLAY ADOBE, SECOND CROP

MILO A (following oats)

Planted, June 3, 1916. Harvested, November 16, 1916

Pot	No. plants	Straw		Grain		Total dry matter		Notes
		Weight	Average weight	Weight	Average weight	Weight	Average weight	
1-1	8	4.87		.....		4.87		Excluded from average
1-2	8	10.00		.....		10.00		
1-3	7	4.50	4.68	.....	.....	4.50	4.68	
2-1	8	2.59		.....		2.59		
2-2	8	3.73		.....		3.73		
2-3	8	2.92	3.08	.....	.....	2.92	3.08	
5-1	8	4.03		.....		4.03		
5-2	6	5.13		.....		5.13		
5-3	7	8.44		.....		8.44		
6-1	9	3.49		.....		3.49		
6-2	8	3.08		.....		3.08		
6-3	8	2.98	3.18	.....	.....	2.98	3.18	

TABLE 52—DIABLO CLAY ADOBE, SECOND CROP

MILO B (following oats and bur clover)

Planted, June 3, 1916. Harvested, November 16, 1916

Pot	No. plants	Straw		Grain		Total dry matter		Notes
		Weight	Average weight	Weight	Average weight	Weight	Average weight	
1-1	8	6.41		.....		6.41		
1-2	8	8.78		.....		8.78		
1-3	8	6.21	7.14	.....	.....	6.21	7.14	
2-1	8	3.92		.....		3.92		
2-2	8	4.52		.....		4.52		
2-3	8	3.63	4.02	.....	.....	3.63	4.02	
5-1	8	10.34		.....		10.34		
5-2	8	6.17		.....		6.17		
5-3	8	5.20	7.24	.....	.....	5.20	7.24	
6-1	8	9.29		.....		9.29		
6-2	8	3.70		.....		3.70		
6-3	8	4.09	5.69	.....	.....	4.09	5.69	

TABLE 53—DIABLO CLAY ADOBE, SECOND CROP

MILLET (following bur clover)

Planted, June 3, 1916. Harvested, October 6, 1917

Pot	No. plants	Straw		Grain		Total dry matter		Notes
		Weight	Average weight	Weight	Average weight	Weight	Average weight	
1-1	12	1.52		1.44		2.96		
1-2	11	1.34		0.90		2.24		
1-3	11	2.03	1.63	1.15	1.16	3.18	2.79	
2-1	12	1.26		1.29		2.55		
2-2	11	1.49		1.32		2.80		
2-3	12	0.93	1.23	0.88	1.16	1.80	2.39	
5-1	10	2.26		2.19		4.45		
5-2	12	3.35		3.36		6.71		
5-3	12	2.02	2.54	1.51	2.35	3.53	4.90	
6-1	11	1.19		0.99		2.18		
6-2	12	1.59		1.23		2.82		
6-3	13	1.26	1.35	1.04	1.09	2.29	2.43	

TABLE 54—DIABLO CLAY ADOBE, SECOND CROP

COWPEAS (following wheat)

Planted, August 10, 1916. Harvested, November 16, 1916

Pot	No. plants	Straw		Grain		Total dry matter		Notes
		Weight	Average weight	Weight	Average weight	Weight	Average weight	
1-1	7	2.66		.....		2.66		
1-2	7	5.30		.....		5.30		
1-3	7	3.73	3.89	.....	.....	3.73	3.89	
2-1	6	2.57		.....		2.57		
2-2	6	4.24		.....		4.24		
2-3	6	2.86	3.22	.....	.....	2.86	3.22	
5-1	6	2.74		.....		2.74		
5-2	6	4.30		.....		4.30		
5-3	6	3.64	3.56	.....	.....	3.64	3.56	
6-1	6	3.28		.....		3.28		
6-2	7	4.10		.....		4.10		
6-3	6	3.41	3.60	.....	.....	3.41	3.60	

TABLE 55—DIABLO CLAY ADOBE, SECOND CROP
SOY BEANS (following barley)
Planted, June 6, 1916. Harvested, November 14, 1916

Pot	No. plants	Straw		Grain		Total dry matter		Notes
		Weight	Average weight	Weight	Average weight	Weight	Average weight	
1-1	6	8.48		0.29		8.77		
1-2	6	8.58		0.06		8.64		
1-3	6	6.87	7.98	0.41	0.25	7.28	8.23	
2-1	6	2.12		.....		2.12		Excluded from average
2-2	4	3.62		0.40		4.02		
2-3	5	6.07	4.84	0.38	0.39	6.45	5.23	
5-1	6	5.84		0.16		6.00		
5-2	6	7.96		0.64		8.60		
5-3	6	6.47	6.76	0.69	0.49	7.16	7.25	
6-1	6	7.61		0.24		7.85		
6-2	6	7.99		0.45		8.43		
6-3	6	7.26	7.62	0.17	0.28	7.43	7.90	

Altamont clay loam. First crop.—The crops planted in this soil were wheat, barley, oats, bur clover, *Phaseolus*, and oats and bur clover together. The standard number to which the plants were thinned was six, except in the oats and bur clover series, where three plants of each were allowed to remain.

With regard to the comparative crop producing power of these soils under these conditions, soil no. 4 is the best, with soil no. 3 as the second, and soil no. 7 was the poorest (tables 56-60, fig. 29). The dry weight data decidedly corroborate the impression given by the greenhouse appearance of the crops. However, as all the crops were so small on all the series, the figures do not show as much as they might have shown had the growth been more nearly optimum for the several crops.

TABLE 56—ALTAMONT CLAY LOAM, FIRST CROP
WHEAT
Planted, February 25, 1916. Harvested, July 10, 1916

Pot	No. plants	Straw		Grain		Total dry matter		Notes
		Weight	Average weight	Weight	Average weight	Weight	Average weight	
3-1	6	2.62		1.23		3.85		
3-2	6	2.93		1.09		3.92		
3-3	6	2.86	2.80	1.04	1.12	3.91	3.92	
4-1	6	4.20		1.78		5.97		
4-2	6	4.03		1.22		5.25		
4-3	6	6.20	4.81	1.13	1.38	7.34	6.19	
7-1	6	2.64		1.11		3.76		
7-2	6	2.58		0.99		3.64		
7-3	6	2.90	2.71	0.71	0.93	3.61	3.64	

TABLE 57—ALTAMONT CLAY LOAM, FIRST CROP

BARLEY

Planted, April 4, 1916. Harvested, July 11, 1916

Pot	No. plants	Straw		Grain		Total dry matter		Notes
		Weight	Average weight	Weight	Average weight	Weight	Average weight	
3-1		1.10		0.76		1.86		
3-2		1.45		1.40		2.85		
3-3		1.39	1.31	1.18	1.11	2.57	2.43	
4-1		1.99		1.43		3.42		
4-2		1.90		1.57		3.47		
4-3		2.39	2.09	1.85	1.62	4.25	3.71	
7-1		0.98		0.90		1.88		
7-3		1.06	1.00	0.59	0.71	1.64	1.71	

TABLE 58—ALTAMONT CLAY LOAM, FIRST CROP

OATS

Planted, February 25, 1916. Harvested July 11, 1916

Pot	No. plants	Straw		Grain		Total dry matter		Notes
		Weight	Average weight	Weight	Average weight	Weight	Average weight	
3-1	6	1.36		0.38		1.74		
3-2	6	1.60		0.67		2.27		
3-3	6	1.70	1.55	0.47	0.51	2.17	2.06	
4-1	6	3.05		1.42		4.47		
4-2	4	2.62		1.13		3.76		
4-3	4	3.46	3.04	1.81	1.45	5.27	4.50	
7-1	6	1.21		0.29		1.51		
7-2	6	1.00		0.42		1.42		
7-3	6	0.88	1.03	0.35	0.35	1.23	1.38	

TABLE 58—ALTAMONT CLAY LOAM, FIRST CROP

BUR CLOVER

Planted, February 25, 1916. Harvested, July 8, 1916

Pot	No. plants	Straw		Grain		Total dry matter		Notes
		Weight	Average weight	Weight	Average weight	Weight	Average weight	
3-1	6	1.50		1.03		2.53		
3-2	6	0.88		1.17		2.18		
3-3	6	0.63	1.00	1.34	1.18	1.96	2.18	
4-1	6	2.48		1.47		3.95		
4-2	6	2.57		1.57		4.14		
4-3	4	2.50	2.52	1.31	1.45	3.81	3.97	
7-1	6	0.47		0.66		1.13		
7-2	6	0.53		0.24		0.78		
7-3	6	0.37	0.46	0.20	0.36	0.57	0.82	

TABLE 59—ALTIMONT CLAY LOAM, FIRST CROP
OATS AND BUR CLOVER

Planted, April 14, 1916. Harvested, July 8, 1916

Pot	No. plants	Straw		Grain		Total dry matter		Notes
		Weight	Average weight	Weight	Average weight	Weight	Average weight	
3-1	B. C. 3	0.98		1.25		2.23		
	Oats 3	0.77		0.10		0.88		
3-2	B. C. 4	0.79		1.17		1.96		
	Oats 4	0.68		0.22		0.90		
3-3	B. C. 4	0.48		0.91		1.38		
	Oats 4	0.78	1.49	0.30	1.32	1.07	2.81	
4-1	B. C. 3	0.67		0.32		0.99		
	Oats 3	2.42		1.75		4.17		
4-2	B. C. 3	0.40		0.62		1.01		
	Oats 3	2.63		1.38		4.01		
4-3	B. C. 3	0.51		0.21		0.72		
	Oats 3	2.77	3.14	1.09	1.78	3.86	4.92	
7-1	B. C. 3	0.20		0.27		0.47		
	Oats 3	0.86		0.74		1.60		
7-2	B. C. 3	0.28		0.22		0.50		
	Oats 3	1.27		0.95		2.22		
7-3	B. C. 4	0.42		0.37		0.74		
	Oats 2	0.64	1.22	0.44	0.98	1.08	2.20	

TABLE 60—ALTIMONT CLAY LOAM, FIRST CROP
BEANS (*Phaseolus*)

Planted, February 25, 1916. Harvested, July 11, 1916

Pot	No. plants	Straw		Grain		Total dry matter		Notes
		Weight	Average weight	Weight	Average weight	Weight	Average weight	
3-1	6	2.82		0.13		2.96		
3-2	6	1.24		0.35		1.59		
3-3	6	1.32	1.79	0.32	0.27	1.64	2.06	
4-1	5	1.71		0.25		1.96		
4-2	6	1.41		0.59		2.01		
4-3	6	1.81	1.64	0.59	0.48	2.41	2.12	
7-1	1	0.11		0.09		0.20		
7-2	6	0.53		.....		0.53		
7-3	5	0.63	0.43	.....	0.03	0.63	0.46	

Altamont clay loam. Second crop.—A slightly different scheme was used in the planting of this series, only three crops were used, i.e., soy beans, cowpeas, and milo. Two sets of pots were planted to each crop, one of the two sets having previously been planted to a legume, and the other to a non-legume. The milo was thinned so that

one pot of each triplicate set would have 8 plants, the second of the set 12 plants, and the last 16 plants. It was found that the wide variation in the number of plants had but little effect upon the dry weight produced per pot (tables 61-66). The effect was indeed so slight that the totals were averaged up as usual. Figure 30 shows distinctly that there was very little variation as regards total production among these soils, so little as not to warrant any conclusions as regards substantiation of, or disagreement with, the first crop. It will be noticed in the second crop of the Diablo series, as well as in that of the Altamont series, that the maintenance of the soils under the same conditions for a year or more seems to bring them quite rapidly to an average crop producing power.

TABLE 61—ALTAMONT CLAY LOAM, SECOND CROP
MILO A (following wheat)

Planted, August 10, 1916. Harvested, November 17, 1916

Pot	No. plants	Straw		Grain		Total dry matter		Notes
		Weight	Average weight	Weight	Average weight	Weight	Average weight	
3-1	8	0.77		.....		0.77		
3-2	12	1.01		.....		1.01		
3-3	16	0.97	0.92	.....	.....	0.97	0.92	
4-1	8	1.22		.....		1.22		
4-2	12	2.32		.....		2.32		
4-3	16	2.08	1.87	.....	.....	2.08	1.87	
7-1	8	0.59		.....		0.59		
7-2	12	0.99		.....		1.29		
7-3	16	1.29	0.95	.....	.....	1.29	0.95	

TABLE 62—ALTAMONT CLAY LOAM, SECOND CROP
MILO B

Planted, August 10, 1916. Harvested, November 15, 1916

Pot	No. plants	Straw		Grain		Total dry matter		Notes
		Weight	Average weight	Weight	Average weight	Weight	Average weight	
3-1	8	0.82		.....		0.82		
3-2	12	1.13		.....		1.13		
3-3	16	1.15	1.03	.....	.....	1.15	1.03	
4-1	8	1.28		.....		1.28		
4-2	12	1.82		.....		1.82		
4-3	16	1.45	1.52	.....	.....	1.45	1.52	
7-1	8	0.66		.....		0.66		
7-2	12	0.96		.....		0.96		
7-3	16	0.92	0.85	.....	.....	0.92	0.85	

TABLE 63—ALTAMONT CLAY LOAM, SECOND CROP

COWPEAS A (following barley)

Planted, August 10, 1916. Harvested, November 17, 1916

Pot	No. plants	Straw		Grain		Total dry matter		Notes
		Weight	Average weight	Weight	Average weight	Weight	Average weight	
3-1	6	3.48		.....		3.48		
3-2	6	4.50		.....		4.50		
3-3	6	3.00	3.66	.....	.....	3.00	3.66	
4-1	6	2.44		.....		2.44		
4-2	6	2.59		.....		2.59		
4-3	6	3.40	2.81	.....	.....	3.40	2.81	
7-1	6	2.64		.....		2.64		
7-2	6	1.93		.....		1.93		
7-3	6	2.15	2.24	.....	.....	2.15	2.24	

TABLE 64—ALTAMONT CLAY LOAM, SECOND CROP

COWPEAS B (following oats and bur clover)

Planted, August 10, 1916. Harvested, November 14, 1916

Pot	No. plants	Straw		Grain		Total dry matter		Notes
		Weight	Average weight	Weight	Average weight	Weight	Average weight	
3-1	6	4.16		.....		4.16		
3-2	6	3.63		.....		3.63		
3-2	6	2.77	3.52	.....	.....	2.77	3.52	
4-1	6	3.35		.....		3.35		
4-2	6	2.70		.....		2.70		
4-3	6	1.94	2.66	.....	.....	1.94	2.66	
7-1	6	1.51		.....		1.51		
7-2	6	2.10		.....		2.10		
7-3	6	2.85	2.15	.....	.....	2.85	2.15	

TABLE 65—ALTAMONT CLAY LOAM, SECOND CROP

SOY BEANS A (following oats)

Planted, August 10, 1916. Harvested, November 17, 1916

Pot	No. plants	Straw		Grain		Total dry matter		Notes
		Weight	Average weight	Weight	Average weight	Weight	Average weight	
3-1	6	4.85		.....		4.85		
3-2	6	4.25		.....		4.25		
3-3	6	4.50	4.53	.....	.....	4.50	4.53	
4-1	6	3.53		.....		3.53		
4-2	6	3.59		.....		3.59		
4-3	6	4.88	4.00	.....	.....	4.88	4.00	
7-1	6	3.42		.....		3.42		
7-2	6	3.34		.....		3.34		
7-3	6	3.42	3.39	.....	.....	3.42	3.39	

TABLE 66—ALTAMONT CLAY LOAM, SECOND CROP

SOY BEANS (following *Phaseolus*)

Planted, August 10, 1916. Harvested November 17, 1916

Pot	No. plants	Straw		Grain		Total dry matter		Notes
		Weight	Average weight	Weight	Average weight	Weight	Average weight	
3-1	6	5.64		.....		5.64		
3-2	6	4.94		.....		4.94		
3-3	6	4.84	5.14	.....	.....	4.84	5.14	
4-1	6	4.74		.....		4.74		
4-2	6	4.64		.....		4.64		
4-3	6	4.71	4.70	.....	.....	4.71	4.70	
7-1	6	5.25		.....		5.25		
7-2	6	3.28		.....		3.28		
7-3	6	4.39	4.31	.....	.....	4.39	4.31	

Hanford fine sandy loam. First crop.—This soil type, with samples from nine different localities in California, gave a much wider range of conditions and made a much more interesting series. The plants used as indicators in this series were milo (twice), millet, cowpeas (twice), and soy beans. The milo was thinned to eight plants per pot, the millet to twelve plants, and the cowpeas and soy beans to six plants. Set A of cowpeas, and set B of milo were unfavorably located, so that the results of these sets should be discounted.

It is interesting to note the large differences in the average weights from soil to soil (tables 67-72, and fig. 31), as compared with the photographs, in which little variation appears. See especially the soy bean series. In this series two things are to be noted:

1. Averages on soils nos. 15 and 25 are hardly representative because in both cases excess moisture, from a leaky roof and too heavy watering, depressed growth. The tendency to become compact and to remain wet and cold shown by soil no. 15 aided the milo and depressed the soy beans.

2. The loose, open texture of soil no. 22 seemingly favored the soy bean growth, though the other plants did not do as well on this soil as on most of the others.

Comparing the more satisfactory grains, milo A and millet, it will be seen that there is somewhat of a parallelism from soil to soil. The legumes do not always respond similarly to the grains, as in the Diablo first crop, yet in the Diablo second crop and the Altamont first and second crops the response of grain and legume seems quite similar. Hence, it is not safe in every case to judge as to the relationships shown by legumes and non-legumes.

Fig. 31

Fig. 31. Graph showing the total dry matter produced by millet, milo (two series), cowpeas (two series), and soy beans on the nine samples of Hanford fine sandy loam. First crop.

Considering all the variations, one might say that soil no. 23 was seemingly among the better soils, and soils nos. 16 and 22 among the poorer soils. Yet when discussing whether the soils be the same or similar, according to the criterion of the dry weight, one of the Hanford groups will be similar according to one crop, and an overlapping group similar according to the second crop. It can be said with reasonable certainty that these Hanford soils are not closely similar to one another.

TABLE 67—HANFORD FINE SANDY LOAM, FIRST CROP

MILO A

Planted, June 10, 1916. Harvested, November 18, 1916

Pot	No. plants	Straw		Grain		Total dry matter		Notes
		Weight	Average weight	Weight	Average weight	Weight	Average weight	
14-1	8	15.34		.....		15.34		Most plants bore no grain; some grain was immature at harvest. These cases noted, but no grain weighed.
14-2	8	12.50		.....		12.50		
14-3	8	10.15	12.66	.....	.....	10.15	12.66	
15-1	8	13.14		.....		13.14		
15-2	8	14.50		.....		14.50		
15-3	5	15.21	14.28	.....	.....	15.21	14.28	Not mature
16-1	8	8.67		.....		8.67		
16-2	8	5.86		.....		5.86		
16-3	8	4.76	6.43	.....	.....	4.76	6.43	
19-1	8	7.65		.....		7.65		
19-2	8	14.11		.....		14.11		
19-3	8	7.01		.....		7.01		
20-1	8	14.10		.....		14.10		
20-2	8	10.15		.....		10.15		
20-3	8	7.68	10.64	.....	.....	7.68	10.64	Not mature
22-1	8	5.34		.....		5.34		
22-2	8	5.88		.....		5.88		
22-3	8	5.35	5.52	.....	.....	5.35	5.52	
23-1	8	8.90		.....		8.90		Not mature
23-2	8	10.04		.....		10.04		Not mature
23-3	8	8.67	9.20	.....	.....	8.67	9.20	
24-1	7	10.82		.....		10.82		
24-2	8	9.92		.....		9.92		Not mature
24-3	8	6.01	8.92	.....	.....	6.01	8.92	Not mature
25-1	8	11.26		.....		11.26		
25-1	8	11.26		.....		11.26		
25-2	8	5.70		.....		5.70		
25-3	8	9.33	8.76	.....	.....	9.33	8.76	

TABLE 68—HANFORD FINE SANDY LOAM, FIRST CROP
MILO B

Planted, June 10, 1916. Harvested, November 20, 1916

Pot	No. plants	Straw		Grain		Total dry matter		Notes
		Weight	Average weight	Weight	Average weight	Weight	Average weight	
14-1	8	10.75		.....		10.75		
14-2	8	10.95		.....		10.95		
14-3	8	8.84	10.18	.....	.....	8.84	10.18	
15-1	5	5.25		.....		5.25		
15-2	4	4.62		.....		4.62		
15-3	2	3.92	4.60	.....	.....	3.92	4.60	
16-1	7	7.36		.....		7.36		
16-2	2	2.18		.....		2.18		
16-3	4	2.74	4.09	.....	.....	2.74	4.09	
19-1	3	3.73		.....		3.73		
19-2	8	4.79		.....		4.79		
19-3	8	9.60	6.04	.....	.....	9.60	6.04	
20-1	8	8.14		.....		8.14		
20-2	8	3.23		.....		3.23		
20-3	8	3.22	4.86	.....	.....	3.22	4.86	
22-1	6	4.74		.....		4.74		
22-2	5	3.01		.....		3.01		
22-3	7	3.19	3.64	.....	.....	3.19	3.64	
23-1	8	5.68		.....		5.68		
23-2	5	7.72		.....		7.72		
23-3	8	6.93	6.78	.....	.....	6.93	6.78	
24-1	3	3.16		.....		3.16		
24-2	6	5.64		.....		5.64		
24-3	6	3.26	4.02	.....	.....	3.26	4.02	
25-1	4	3.07		.....		3.07		
25-2	3	2.34		.....		2.34		
25-3	8	4.34	3.25	.....	.....	4.34	3.25	

TABLE 69—HANFORD FINE SANDY LOAM, FIRST CROP

MILLET

Planted, June 10, 1916. Harvested: Nos. 15-25, September 20, 1916; No. 14, October 6, 1916

Pot	No. plants	Straw		Grain		Total dry matter		Notes
		Weight	Average weight	Weight	Average weight	Weight	Average weight	
14-1	12	3.75		2.90		6.65		
14-2	13	4.23		2.95		7.18		
14-3	14	3.46	3.81	2.01	2.62	5.47	6.43	
15-1	12	3.63		1.02		4.65		
15-2	12	4.63		1.31		5.93		
15-3	12	3.86	4.04	1.12	1.15	4.98	5.19	
16-1	13	1.96		0.74		2.70		
16-2	12	3.10		1.81		4.91		
16-3	12	1.52	2.19	0.73	1.09	2.25	3.29	
19-1	12	1.85		0.73		2.58		Seed immature Poor. Lack of drainage?
19-2	12	1.71		0.76		2.48		
19-3	12	2.00	1.85	0.69	0.73	2.69	2.58	
20-1	12	6.54		2.78		9.32		Possible error in grain weight. Original shows 6 grams
20-2	12	1.70		1.01		2.71		
20-3	12	6.57	6.55	2.21	2.50	8.78	9.05	
22-1	12	2.04		0.65		2.69		
22-2	12	2.32		0.68		3.00		
22-3	12	4.44	2.93	1.90	1.08	6.34	4.01	
23-1	12	6.12		1.21		7.33		
23-2	12	6.13		2.14		8.27		
23-3	12	6.01	6.08	1.97	1.78	7.99	7.86	
24-1	12	4.18		1.50		5.69		
24-2	12	2.80		0.91		3.70		
24-3	11	4.89	3.96	2.08	1.50	6.98	5.46	
25-1	12	2.06		0.77		2.83		
25-2	12	2.01		0.51		2.52		
25-3	12	4.31	2.79	2.15	1.14	6.46	3.94	

TABLE 70—HANFORD FINE SANDY LOAM, FIRST CROP

SOY BEANS

Planted, June 10, 1916. Harvested, December 11, 1916

Pot	No. plants	Straw		Beans		Total dry matter		Notes
		Weight	Average weight	Weight	Average weight	Weight	Average weight	
14-1	6	16.69		.....		16.69		Immature seed
14-2	6	16.28		.....		16.28		Immature seed
14-3	6	11.89	14.95	0.44	0.15	12.33	15.10	Immature seed
15-1	6	14.08		0.23		14.31		Immature seed
15-2	6	5.17		.....		5.17		Immature seed
15-3	6	6.53	8.59	.....	0.08	6.53	8.67	Immature seed
16-1	6	12.63		0.32		12.95		Immature seed
16-2	6	14.60		.....		14.60		Immature seed
16-3	6	16.60	14.61	.....	0.11	16.60	14.72	Immature seed
19-1	6	12.84		.....		12.84		Immature seed
19-2	6	11.68		.....		11.68		Immature seed
19-3	6	16.03	13.52	.....	.....	16.03	13.52	Immature seed
20-1	6	8.77		.....		8.77		Immature seed
20-2	6	16.33		.....		16.33		Immature seed
20-3	6	14.27	13.13	.....	.....	14.27	13.13	Immature seed
22-1	6	20.28		.....		20.28		Immature seed
22-2	6	19.44		.....		19.44		Immature seed
22-3	6	15.60	18.44	.....	.....	15.60	18.44	Immature seed
23-1	6	21.42		.....		21.42		No seed
23-2	6	20.75		.....		20.75		No seed
23-3	6	20.68	20.95	.....	.....	20.68	20.95	Immature seed
24-1	6	17.37		.....		17.37		Immature seed
24-2	6	21.24		.....		21.24		Immature seed
24-3	6	13.70	17.43	.....	.....	13.70	17.43	Immature seed
25-1	6	5.53		.....		5.53		Rained on; excluded from average
25-2	6	17.85		.....		17.85		No seed
25-3	6	21.58	19.71	.....	.....	21.58	19.71	Immature seed

TABLE 71—HANFORD FINE SANDY LOAM, FIRST CROP
COWPEAS A

Planted, June 10, 1916. Harvested, October 21, 1916

Pot	No. plants	Straw		Beans		Total dry matter		Notes
		Weight	Average weight	Weight	Average weight	Weight	Average weight	
14-1	6	2.99		0.93		3.92		
14-2	6	3.52		.....		3.52		
14-3	6	4.18	3.56	.....	.....	4.18	3.87	
15-1	..	.....		.....		.....		
15-2	..	.....		.....		.....		
15-3	..	.....		.....		.....		
16-1	1	2.98		.....		2.98		Immature seed
16-2	3	3.05		1.50		4.58		
16-3	4	2.60	2.88	2.16	1.22	4.76	4.10	
19-1	6	1.49		0.27		1.77		
19-2	6	1.54		0.28		1.82		
19-3	2	1.10	1.38	0.47	0.34	1.57	1.72	
20-1	6	2.86		0.32		3.18		
20-2	6	2.08		0.58		2.66		
20-3	6	2.99	2.64	0.33	0.41	3.32	3.05	
22-1	5	1.80		0.23		2.02		
22-2	..	.....		.....		.....		
22-3	2	1.96	1.88	0.39	0.31	2.35	2.19	
23-1	..	.....		.....		.....		
23-2	1	1.80		0.76		2.57		
23-3	..	.....	1.80	.....	0.76	.....	2.57	
24-1	2	1.06		0.25		1.30		
24-2	1	1.80		1.29		3.09		
24-3	2	1.75	1.54	0.45	0.66	2.20	2.20	
25-1	3	2.74		2.03		4.78		
25-2	1	1.88		2.28		4.17		
25-3	2	2.12	2.25	1.24	1.85	3.36	4.10	

TABLE 72—HANFORD FINE SANDY LOAM, FIRST CROP
COWPEAS B

Planted, June 10, 1916. Harvested, November 21, 1916

Pot	No. plants	Straw		Beans		Total dry matter		Notes
		Weight	Average weight	Weight	Average weight	Weight	Average weight	
14-1	6	3.94		.....		3.94		
14-2	6	5.93		.....		5.92		
14-3	6	3.32	4.39	.....		3.32	4.39	
15-1	6	7.24		.....		7.24		
15-2	6	5.34		.....		5.34		
15-3	6	4.61	5.74	.....		4.61	5.74	
16-1	6	5.90		.....		5.90		
16-2	6	5.82		.....		5.82		
16-3	6	3.65	5.12	.....		3.65	5.12	
19-1	6	3.34		.....		3.34		
19-2	6	3.38		.....		3.38		
19-3	6	3.87	3.53	.....		3.87	3.53	1 died early
20-1	6	3.09		.....		3.09		
20-2	6	3.15		.....		3.15		1 died early
20-3	6	2.80	3.01	.....		2.80	3.01	
22-1	6	3.12		.....		3.12		
22-2	6	3.61		.....		3.61		
22-3	6	4.92	3.88	.....		4.92	3.88	
23-1	6	4.59		.....		4.59		
23-2	6	6.04		.....		6.04		
23-3	6	4.08	4.90	.....		4.08	4.90	
24-1	6	3.81		.....		3.81		
24-2	5	4.28		.....		4.28		
24-3	6	6.42	4.84	.....		6.42	4.84	
25-1	5	4.17		.....		4.17		
25-2	6	3.93		.....		3.93		1 died early
25-3	6	4.86	4.32	.....		4.86	4.32	

Hanford fine sandy loam. Second crop.—Barley (twice), oats, wheat, bur clover (*Medicago* sp.), and *Melilotus indica* were the indicator crops used when the Hanford soils were planted the second time. In all cases a sufficient quantity of seed was used to insure the growth of more plants than would be raised to maturity. Later the plants in each pot were thinned to six in number, good specimens and well

spaced. The final number of plants varied, but was almost always six. An attempt was made to reduce at least partially the shading and exposure effects. The pots were periodically changed from position to position on the bench.

The total dry weights produced on the several soils are interesting (tables 73-78, and fig. 33). The grains gave more uniform results in this crop than in the first. Soils nos. 14 and 23 show the best crops, and they are the ones that have the highest amounts of total nitrogen. The legumes selected must have been particularly well adapted to the growing conditions and the soils, because the growth was enormous. In the amount of dry matter produced the parallelism between the two legumes from soil to soil is close. It is noteworthy that soil no. 14,

Fig. 32

Fig. 32. Graph showing the total dry matter produced by barley, wheat, oats, rye, bur clover, and *Melilotus indica* on the eight samples of San Joaquin sandy loam. First and only crop.

which showed the highest total nitrogen and produced the most dry matter from the grains, gave the poorest crop of legumes. The notes taken during the growing period show that the relative appearances quite early and throughout the period of growth are usually a good index to the relative amounts of dry matter produced. This is so, even though the photographs of the mature plants do not show differences nearly as great in magnitude as do the dry weights.

This type does not show any marked tendency for the several soils to approach a more uniform crop producing capacity through being kept under the same conditions. In fact, the second crop shows greater variations than the first. And this type does not show that these nine soils, mapped under a single type name, are closely similar to one another in crop producing power.

TABLE 73—HANFORD FINE SANDY LOAM, SECOND CROP
WHEAT (following millet)

Planted, October 30, 1916. Harvested, June 21, 1917

Pot	No. plants	Straw		Grain		Total dry matter		Notes
		Weight	Average weight	Weight	Average weight	Weight	Average weight	
14-1	6	10.75		3.55		14.30		
14-2	5	5.20		2.10		7.30		
14-3	6	14.85	10.26	6.45	4.03	21.30	14.30	
15-1	6	3.55		1.30		4.65		
15-2	6	4.85		1.50		6.35		
15-3	6	2.80	3.66	1.10	1.30	3.90	4.96	
16-1	6	3.20		0.95		4.15		
16-2	6	8.20		3.70		11.90		Rained on, excluded from average
16-3	6	2.80	3.00	0.70	0.82	3.50	3.82	
19-1	6	2.80		0.75		3.55		
19-2	6	2.80		0.65		3.45		
19-3	6	2.20	2.60	0.60	0.66	2.80	3.26	
20-1	6	5.45		2.80		8.25		
20-2	6	4.05		1.55		5.60		
20-3	6	21.35	4.75	12.90	2.17	34.25	6.90	Rained on, excluded from average
22-1	6	4.15		0.90		5.05		
22-2	6	3.95		0.40		4.35		
22-3	6	4.45	4.18	0.90	0.73	5.35	4.92	
23-1	6	4.90		1.60		6.50		
23-2	6	4.75		1.60		6.35		
23-3	6	3.75	4.46	1.10	1.43	4.85	5.90	
24-1	6	18.60		8.30		26.90		Rained on, excluded from average
24-2	6	3.20		0.90		4.10		Rained on, excluded from average
24-3	6	23.75	3.20	5.40	0.90	29.15	4.10	Rained on, excluded from average
25-1	6	15.75		9.05		24.80		
25-2	6	2.50		0.35		2.85		
25-3	6	2.25	2.37	0.80	0.57	3.05	2.95	

TABLE 74—HANFORD FINE SANDY LOAM, SECOND CROP
OATS (following milo A)

Planted, November 22, 1916. Harvested, June 18, 1917

Pot	No. plants	Straw		Grain		Total dry matter		Notes
		Weight	Average weight	Weight	Average weight	Weight	Average weight	
14-1	6	3.80		2.90		6.70		
14-2	6	3.40		1.85		5.25		
14-3	6	3.20	3.47	2.40	2.38	5.65	5.86	
15-1	6	2.45		1.35		3.80		
15-2	6	1.75		1.25		3.00		
15-3	6	2.00	2.06	1.50	1.36	3.50	3.43	
16-1	6	11.15		8.40		19.55		Rained on, excluded from average
16-2	6	2.15		2.30		4.45		Pot saturated with soluble salts, excluded from average
16-3	6	1.15	2.15	0.70	2.30	1.85	4.45	
19-1	6	1.75		1.25		3.00		
19-2	6	4.55		2.95		7.50		
19-3	6	1.35	2.55	0.95	1.72	2.30	4.27	
20-1	6	10.45		6.30		16.75		Rained on, excluded from average
20-2	6	1.55		1.05		2.60		
20-3	6	1.65	1.60	1.00	1.02	2.65	2.62	
22-1	6	1.65		1.10		2.75		
22-2	6	2.10		1.15		3.25		
22-3	6	2.50	2.08	1.50	1.25	4.00	3.33	
23-1	6	2.70		1.55		4.25		
23-2	6	1.90		1.60		3.50		
23-3	6	3.20	2.60	2.00	1.71	5.20	4.32	
24-1	6	4.80		3.10		7.90		
24-2	6	16.75		9.80		26.55		Rained on, excluded from average
24-3	6	3.35	4.07	2.35	2.73	5.70	6.80	
25-1	6	1.95		1.30		3.25		
25-3	6	2.25	2.00	1.40	1.30	3.65	3.30	
25-2	6	1.80		1.20		3.00		

TABLE 75—HANFORD FINE SANDY LOAM, SECOND CROP
BARLEY A (following cowpeas A)

Planted, October 30, 1916. Harvested, May 20, 1917

Pot	No. plants	Straw		Grain		Total dry matter		Notes
		Weight	Average weight	Weight	Average weight	Weight	Average weight	
14-1	6	4.75		4.30		9.05		
14-2	6	9.22		9.00		18.22		
14-3	6	11.97	8.65	10.85	8.05	22.82	16.69	
15-1	6	15.47		15.30		30.77		Rained on, excluded from average
15-2	6	3.78		3.29		7.07		
15-3	6	5.00	4.39	4.12	3.70	9.12	8.09	
16-1	6	7.28		6.42		13.70		
16-2	6	2.55		2.55		5.10		
16-3	6	2.20	4.01	1.71	3.56	3.91	7.57	
19-1	6	2.82		1.80		4.62		
19-2	6	2.39		1.91		4.30		
19-3	6	2.89	2.70	2.25	1.98	5.14	4.68	
20-1	6	3.57		2.90		6.47		
20-2	6	3.32		2.80		6.12		
20-3	6	19.35	3.44	7.45	2.85	26.70	6.29	Rained on, excluded from average
22-1	6	2.73		2.07		4.80		
22-2	6	5.89		3.53		9.42		
22-3	6	3.69	4.10	2.73	2.78	6.42	6.88	
23-1	6	5.29		3.35		8.64		
23-2	6	6.19		4.23		10.42		
23-3	6	7.98	6.24	4.20	3.93	12.18	10.41	
24-1	6	3.07		2.54		5.61		
24-2	6	21.85		9.75		31.60		
24-3	6	4.73	3.90	3.57	3.05	8.30	6.95	
25-1	6	2.47		1.75		4.22		Rained on, excluded from average
25-2	6	Lost		.....		.....		Pot broken, excluded from average
25-3	6	3.01	2.74	2.18	1.96	5.19	4.70	

TABLE 76—HANFORD FINE SANDY LOAM, SECOND CROP
BARLEY B (following soy beans)

Planted, January 31, 1917. Harvested, June 21, 1917

Pot	No. plants	Straw		Grain		Total dry matter		Notes
		Weight	Average weight	Weight	Average weight	Weight	Average weight	
14-1	6	9.55		6.80		16.35		
14-2	6	6.05		5.40		11.45		
14-3	6	3.80	6.47	2.10	4.76	5.90	11.23	
15-1	6	3.50		2.80		6.30		
15-2	6	3.20		1.70		4.90		
15-3	6	4.05	3.58	2.60	2.36	6.65	5.95	
16-1	6	3.10		1.45		4.55		
16-2	6	9.20		8.20		17.40		Rained on, exclud- ed from average
16-3	6	7.35	3.10	4.50	1.45	11.85	4.55	Rained on, exclud- ed from average
19-1	6	3.05		0.80		3.85		
19-2	6	2.65		2.20		4.85		
19-3	6	2.15	2.62	1.85	1.61	4.00	4.23	
20-1	6	3.35		2.60		5.95		
20-2	6	4.20		3.20		7.40		
20-3	6	2.55	3.36	2.15	2.65	4.70	6.02	
22-1	6	2.05		1.75		3.80		
22-2	6	2.90		2.35		5.25		
22-3	6	3.15	2.70	2.25	2.12	5.40	4.82	
23-1	6	3.10		2.05		5.15		
23-2	6	3.10		2.95		6.05		
23-3	6	3.40	3.20	2.75	2.58	6.15	5.78	
24-1	6	3.10		1.45		3.70		
24-2	6	10.10		5.80		15.90		Rained on, exclud- ed from average
24-3	6	3.05	2.65	2.35	1.90	5.40	4.55	
25-1	6	3.35		2.90		6.25		
25-2	6	3.10		1.85		4.95		
25-3	6	4.70	3.72	4.60	3.12	9.30	6.83	

TABLE 77—HANFORD FINE SANDY LOAM, SECOND CROP

Melilotus indica (following cowpeas B)

Planted, November 22, 1916. Harvested, June 21, 1917

Pot	No. plants	Straw		Unhulled seed		Total dry matter		Notes
		Weight	Average weight	Weight	Average weight	Weight	Average weight	
14-1	6	17.00		15.80		32.80		
14-3	6	13.25		16.45		29.70		
14-3	6	4.40	15.12	3.10	16.12	7.50	31.25	Excluded from average
15-1	6	35.00		34.75		69.75		
15-2	6	24.85		27.28		52.05		
15-3	6	28.95	29.60	32.70	31.58	61.65	61.15	
16-1	5	23.50		24.90		48.40		
16-2	6	30.80		25.50		56.30		
16-3	6	23.65	25.98	25.70	25.37	49.35	51.35	
19-1	6	20.50		18.35		38.85		
19-2	6	26.90		23.20		50.10		
19-3	6	26.20	24.53	27.40	22.98	53.60	47.52	
20-1	6	20.55		17.80		38.35		
20-2	6	20.75		21.20		41.95		
20-3	6	28.85	23.38	26.05	21.68	54.90	45.07	
22-1	6	28.00		28.10		56.10		
22-2	6	32.30		34.20		66.50		
22-3	6	28.25	29.52	31.85	31.38	60.10	60.90	
23-1	6	38.05		34.25		72.30		
23-2	6	34.40		36.55		70.95		
23-3	6	32.25	34.90	32.35	34.38	64.60	69.28	
24-1	6	37.35		31.40		68.75		
24-2	6	25.90		28.10		54.00		
24-3	6	29.05	30.77	30.15	29.88	59.20	60.65	
25-1	6	25.35		30.45		55.80		
25-2	6	33.90		35.90		69.80		
25-3	6	32.10	30.45	36.65	34.33	68.75	64.78	

TABLE 78—HANFORD FINE SANDY LOAM, SECOND CROP
BUR CLOVER (following milo B)
Planted, November 22, 1916. Harvested, June 25, 1917

Pot	No. plants	Straw		Burs		Total dry matter		Notes
		Weight	Average weight	Weight	Average weight	Weight	Average weight	
14-1	7	6.70		17.55		24.25		
14-2	6	7.00		16.85		23.85		
14-3	6	6.10	6.60	14.50	16.30	20.60	22.90	
15-1	6	13.30		29.10		42.40		
15-2	6	14.45		33.10		47.55		
15-3	6	17.10	14.95	26.65	29.62	43.75	44.56	
16-1	6	8.85		15.40		24.25		
16-2	6	12.25		29.60		41.85		
16-3	6	10.05	10.38	21.90	22.30	31.95	32.68	
19-1	6	9.90		19.90		29.80		
19-2	6	7.70		17.80		25.50		
19-3	6	8.20	8.60	22.40	20.03	30.60	28.63	
20-1	6	7.90		22.50		30.40		
20-2	6	9.75		23.30		33.05		
20-3	6	8.70	8.78	20.50	22.10	29.20	30.88	
22-1	6	15.90		38.00		53.90		
22-2	6	13.20		23.40		36.60		
22-3	6	14.50	14.53	31.30	30.90	45.80	45.43	
23-1	6	14.45		37.40		51.85		
23-2	6	13.55		27.30		40.85		
23-3	6	12.05	13.35	28.00	30.90	40.05	44.25	
24-1	6	10.60		24.30		34.90		
24-2	6	12.10		34.10		46.20		
24-3	6	10.25	10.98	24.00	27.46	34.25	38.45	
25-1	6	17.90		40.00		57.90		
25-2	6	14.60		30.80		45.40		
25-3	6	13.35	15.28	26.40	32.40	39.75	47.68	

San Joaquin sandy loam.—The samples of this type were the last to be weighed into pots and planted, because of the lack of available greenhouse space; therefore the time allowed for the growing of but one crop, instead of two, on each pot of soil. The crops used were wheat, barley, rye, oats, bur clover (*Medicago* sp.), and *Melilotus indica*. As was done for the other types, an excess of seed was planted. When the plants were well established, thinning reduced the number to six plants per pot.

Since the specific gravity of this soil was high, because of the large amount of quartz and the small amount of organic matter in its composition, six kilos of soil, instead of five, were weighed out into each pot. The samples of this type have the very annoying peculiarities of becoming very mushy if an excess of water be added, and of setting

with a very hard surface on drying. This makes the soils hard to handle in greenhouse pot culture work.

The variation in crop growth from soil to soil, as shown by the total dry matter produced (tables 79-84 and fig. 32), is rather marked. That the several samples do not show equal crop producing powers is very evident, though with regard to the several indicator crops the soils would frequently not maintain the same order. Soil no. 26 gave the poorest yields with all six crops. Except for wheat, the soils nos. 10, 11, and 12 gave low yields with both the grains and the legumes. It is interesting to note that wheat gave relatively high yields with a number of the soils, and wheat has probably been raised on these soils more than any other one crop. This series shows that, as far as the samples represent the type and the crops used represent crops as a whole, the soils mapped under a given type name are not closely similar in crop producing power under greenhouse conditions.

TABLE 79—SAN JOAQUIN SANDY LOAM

RYE

Planted, November 22, 1916. Harvested, June 21, 1917

Pot	No. plants	Straw		Grain		Total dry matter		Notes
		Weight	Average weight	Weight	Average weight	Weight	Average weight	
10-1	6	1.70		0.30		2.00		
10-2	6	2.30		0.35		2.65		
10-3	6	2.05	2.02	0.65	0.43	2.70	2.45	
11-1	6	3.15		0.70		3.85		
11-2	6	2.25		0.70		2.95		
11-3	4	3.20	2.87	0.70	0.70	3.90	3.57	
12-1	6	1.65		0.45		2.10		
12-2	6	2.45		0.85		3.30		
12-3	6	2.40	2.17	0.65	0.65	3.05	2.82	
13-1	6	4.20		1.25		5.45		
13-2	6	4.30		0.80		5.10		
13-3	6	3.75	4.08	1.60	1.22	5.35	5.30	
17-1	6	7.55		1.60		9.15		Rained on
17-2	6	1.95		0.55		2.50		
17-3	6	1.80	1.87	0.45	0.50	2.25	2.37	
18-1	6	2.35		0.85		3.20		
18-2	6	0.90		0.30		1.20		
18-3	6	3.70	2.32	1.20	0.78	4.90	3.10	
21-1	6	2.20		0.80		3.00		
21-2	6	2.70		0.95		3.65		
21-3	6	6.55	2.45	2.35	0.87	8.90	3.33	Rained on
26-1	6	1.50		0.60		2.10		
26-2	6	2.55		0.75		3.30		
26-3	6	2.50	2.18	0.70	0.68	3.20	2.87

Fig. 33. Graph showing the total dry matter produced by wheat, oats, barley (two series), bur clover, and *Melilotus indica* on the nine samples of Hanford fine sandy loam. Second crop.

TABLE 80—SAN JOAQUIN SANDY LOAM

BARLEY

Planted, October 30, 1916. Harvested, June 17, 1917

Pot	No. plants	Straw		Grain		Total dry matter		Notes
		Weight	Average weight	Weight	Average weight	Weight	Average weight	
10-1	6	2.93		0.92		3.85		
10-2	6	1.87		0.81		2.68		
10-3	6	1.47	2.09	0.85	0.86	2.32	2.95	
11-1	6	1.91		0.66		2.57		
11-2	6	2.02		1.28		3.30		
11-3	6	2.97	2.30	0.90	0.95	3.87	3.25	
12-1	6	10.27		4.95		15.22		Rained on; excluded from average
12-2	6	3.60		1.32		4.92		
12-3	6	3.49	3.54	0.43	0.87	3.92	4.42	
13-1	6	2.14		1.46		3.60		
13-2	6	3.19		1.78		4.97		
13-3	6	3.28	2.87	1.77	1.67	5.05	4.53	
17-1	6	3.89		2.17		6.06		
17-2	6	3.74		1.80		5.54		
17-3	6	2.44	3.35	0.80	1.59	3.24	4.95	
18-1	6	4.65		1.93		6.58		
18-2	6	3.74		1.94		5.68		
18-3	6	5.61	4.66	2.34	2.07	7.95	6.74	
21-1	6	2.05		1.53		3.58		
21-2	6	2.10		1.80		3.90		
21-3	6	3.81	2.65	2.33	1.88	6.14	4.54	
26-1	6	1.12		0.63		1.75		
26-2	6	1.08		0.41		1.49		
26-3	6	1.20	1.13	0.70	0.58	1.90	1.71	

TABLE 81—SAN JOAQUIN SANDY LOAM

WHEAT

Planted, October 30, 1916. Harvested, June 21, 1917

Pot	No. plants	Straw		Grain		Total dry matter		Notes
		Weight	Average weight	Weight	Average weight	Weight	Average weight	
10-1	6	3.59		0.85		4.80		
10-2	6	3.45		0.45		3.90		
10-3	6	6.35	4.58	0.75	0.68	7.10	5.26	
11-1	6	5.60		1.15		6.75		
11-2	6	2.75		0.60		3.35		
11-3	6	3.45	3.93	0.70	0.81	4.15	4.75	
12-1	6	6.85		2.00		8.85		
12-2	6	7.50		1.35		8.85		
12-3	6	4.45	6.27	1.35	1.56	5.80	7.83	
13-1	6	3.90		0.85		4.75		
13-2	6	3.25		0.45		3.70		
13-2	6	3.95	3.70	0.75	0.68	4.70	4.38	
17-1	6	2.70		0.25		2.95		
17-2	6	1.20		0.45		1.65		
17-3	6	2.75	2.21	none	0.23	2.75	2.45	
18-1	6	5.90		1.50		7.40		
18-2	6	7.90		2.40		10.30		Rained on
18-3	6	5.00	5.45	1.00	1.25	6.00	6.70	
21-1	6	3.10		1.05		4.15		
21-2	5	4.30		0.75		5.05		
21-3	6	8.40	3.70	2.45	0.90	10.85	4.60	Rained on
26-1	6	2.35		0.55		2.90		
26-2	6	0.40		none		0.40		Rained on
26-3	6	2.60	2.47	0.35	0.45	2.95	2.92	

TABLE 82—SAN JOAQUIN SANDY LOAM
OATS

Planted, November 22, 1916. Harvested, June 17, 1917

Pot	No. plants	Straw		Grain		Total dry matter		Notes
		Weight	Average weight	Weight	Average weight	Weight	Average weight	
10-1	6	2.25		0.90		3.15		
10-2	6	3.65		1.90		5.55		
10-3	6	1.70	2.53	0.50	1.10	2.20	3.63	
11-1	6	2.25		1.25		3.50		
11-2	6	1.75		0.95		2.70		
11-3	6	2.10	2.03	1.00	1.07	3.10	3.10	
12-1	6	1.70		0.90		2.60		
12-2	6	2.40		1.00		3.40		
12-3	6	2.35	2.15	1.05	0.98	3.40	3.13	
13-1	6	2.25		1.20		3.45		
13-2	6	2.40		1.10		3.50		
13-3	6	2.70	2.45	1.70	1.33	4.40	3.78	
17-1	6	0.80		0.55		1.35		
17-2	6	1.50		0.90		2.40		
17-3	6	1.25	1.90	0.70	0.72	1.95	1.90	
18-1	6	1.70		1.00		2.70		
18-2	6	1.15		0.60		1.75		
18-3	6	1.10	1.32	0.50	0.70	1.60	2.02	
21-1	6	1.85		0.95		2.80		
21-2	6	2.35		1.05		3.40		
21-3	6	1.00	1.73	0.55	0.85	1.55	2.58	
26-1	6	1.55		0.60		2.15		
26-2	6	1.35		0.80		2.15		
26-3	6	1.65	1.52	0.70	0.70	2.35	2.22	

TABLE 83—SAN JOAQUIN SANDY LOAM
BUR CLOVER

Planted, November 22, 1916. Harvested, June 17, 1917

Pot	No. plants	Straw		Seed in burs		Total dry matter		Notes
		Weight	Average weight	Weight	Average weight	Weight	Average weight	
10-1	6	0.50		0.95		1.45		
10-2	6	1.50		1.65		3.15		
10-3	6	0.50	0.83	1.75	1.45	2.25	2.28	
11-1	6	0.90		2.00		2.90		
11-2	6	0.25		1.00		1.25		
11-3	6	0.30	0.48	1.10	1.37	1.40	1.85	
12-1	6	0.90		3.00		3.90		
12-2	6	2.15		5.30		7.45		
12-3	6	1.50	1.52	1.90	3.40	3.40	4.92	
13-1	6	1.55		3.45		5.00		
13-2	6	0.75		2.80		3.55		
13-3	6	4.35	1.15	5.70	3.12	9.05	4.27	Excluded from av- erage
17-1	6	0.70		2.05		2.75		
17-2	6	2.35		3.85		6.20		Excluded from av- erage
17-3	6	0.90	0.80	1.70	1.87	2.60	2.67	
18-1	6	1.20		3.40		4.60		
18-2	6	3.25		6.65		9.90		Excluded from av- erage
18-3	6	1.80	1.50	4.85	4.12	6.65	5.62	
21-1	6	3.35		3.70		7.05		
21-2	6	2.00		3.90		5.90		
21-3	6	1.75	2.37	5.15	4.25	6.90	6.62	
26-1	6	0.60		1.45		2.05		
26-2	6	1.20		2.75		3.95		
26-3	6	0.40	0.73	1.30	1.83	1.70	2.56	

TABLE 84—SAN JOAQUIN SANDY LOAM

Melilotus indica

Planted, November 22, 1916. Harvested, June 21, 1917.

Pot	No. plants	Straw		Unhulled seed		Total dry matter		Notes
		Weight	Average weight	Weight	Average weight	Weight	Average weight	
10-1	6	1.20		1.20		2.40		
10-2	6	1.03		0.92		1.95		
10-3	6	1.30	1.18	1.65	1.26	2.95	2.44	
11-1	6	1.05		0.85		1.90		
11-2	6	0.50		0.35		0.85		
11-3	6	1.00	0.85	0.80	0.67	1.80	1.52	
12-1	6	1.07		2.05		3.12		
12-2	6	1.70		2.45		4.15		
12-3	6	1.20	1.33	1.40	1.96	2.60	3.29	
13-1	6	3.05		3.70		6.75		
13-2	6	3.10		3.95		7.05		
13-3	6	3.50	3.22	4.45	4.03	7.95	7.25	
17-1	6	3.05		4.05		7.10		
17-2	6	2.25		3.55		5.80		
17-3	6	2.85	2.72	3.20	3.60	6.05	6.32	
18-1	6	3.25		3.90		7.15		
18-2	6	2.05		2.65		4.70		
18-3	6	2.85	2.42	3.95	3.50	6.80	6.22	
21-1	6	2.50		3.40		5.90		
21-2	6	2.65		3.95		6.60		
21-3	6	3.45	2.87	3.30	3.55	6.75	6.42	
26-1	6	1.10		0.85		1.95		
26-2	6	0.95		0.85		1.80		
26-3	6	1.30	1.12	1.05	0.92	2.35	2.04	

GENERAL DISCUSSION

The limited time available for this study made it impossible to make all the determinations upon each of the several horizons of all the soils collected for this study.

It was believed, however, that the additional data were not required, since that already at hand seemed to give ample evidence upon which to base conclusions. Therefore, in many cases determinations were run on the surface horizon only. This makes some of the tables appear incomplete.

On the basis of the preceding results and discussions some general treatment is possible, as well as a more or less critical discussion of the methods of soil surveying pursued by the Bureau of Soils.

The types and the localities of collection of the soils studied were as follows:

<i>Diablo clay adobe:</i>	Thalheim (17)
San Juan Capistrano (1)	Madera (18)
Los Angeles (2)	Merced (21)
Calabasas (5)	Del Mar (26)
Danville (6)	<i>Hanford fine sandy loam:</i>
<i>Altamont clay loam</i>	Elk Grove (14)
Walnut (3)	Acampo (15)
San Fernando Valley (4)	Woodbridge (16)
Mission San José (7)	Waterford (19)
<i>San Joaquin sandy loam:</i>	Snelling (20)
North Sacramento (10)	Basset (22)
Lincoln (11)	Anaheim (23)
Wheatland (12)	Los Angeles (24)
Elk Grove (13)	Van Nuys (25)

NOTE.—Figures following localities designate sample numbers.

COMPARISONS OF PHYSICAL DATA

The mechanical analyses of the soils were carried out with both the Hilgard elutriator and the Bureau of Soils centrifuge methods. The tedious nature of the elutriator method has been emphasized elsewhere. The results by this method show that the soils of each type as a whole are somewhat similar, though no two are identical and some samples of a type are widely divergent from the rest. The Bureau of Soils method appears to give a sharper and more satisfactory separation into classes than does the elutriator method. This is to be expected since the separates represent greater ranges of particle sizes. As a check on the texture of the samples collected, it shows that some of the soils are not true to name, therefore that all soils mapped under a given type name are not closely similar to one another. Of course, this is the belief of many soil surveyors, but it seems strange that in the present work, where there was the attempt to select soils representative of the class and type chosen for study, that such divergences developed. It is an interesting commentary on the personal equation of the field worker, in this case of the writer, who collected the samples.

With regard to the methods of mechanical analysis, one should not overlook Mohr's work on *The Mechanical Analysis of Soils of Java*,³⁰ which gives an excellent discussion of the relative merits of the better known systems of mechanical analysis. He describes a modified centrifuge method preferred by him.

Under a discussion of the physical constants of soils, Free³¹ discusses the value of mechanical analysis as a soil constant, and shows that there are three serious errors in the determination, all of which impress themselves upon one making and using such analyses. They are: "(1) disunity of expression; (2) failure to express conditions within the limits of individual groups; and (3) failure to take account of variations in the shapes of the particles." Yet he emphasizes, and rightly so, "that mechanical analysis is by no means useless nor to be belittled as a means of soil investigation."³²

Moisture equivalents.—This determination showed quite distinct averages for the types, though there was considerable variation within each of the types. Eliminating those samples shown to be non-typical according to the mechanical analysis, the variation within the type is reduced considerably. Yet it cannot be said that as regards this constant that all soils mapped under a given type name, or even those soils under a given type name which the mechanical analysis has shown to be true to name, have closely similar moisture equivalents. Briggs and McLane³³ express the belief that ultimately moisture equivalent determinations will replace mechanical analysis in the classification of soils, because the determination is simple and the result can be expressed as a single constant.

Hygroscopic coefficient.—The two heavy types show averages distinct from those of the two light types, but the wide and erratic variation within the type, together with the nearly universal failure of Briggs and Shantz's formula³⁴ to convert these values into values even approximating those of the moisture equivalent, leads one to doubt the accuracy of these figures of the hygroscopic coefficient. It is because of the ease of determining the moisture equivalent, and because of the difficulties involved in correctly carrying out the hygroscopic coefficient, that the doubt is cast upon the latter determination.

³⁰ Bull. Dept. of Agr., Indes Neerland, 1910, no. 41, pp. 33.

³¹ Free, E. E., *Studies in Soil Physics*, Plant World, vol. 14 (1912), nos. 2, 3, 5, 7, 8.

³² *Ibid.*, p. 29.

³³ Proc. Amer. Soc. Agron., vol. 2 (1910), pp. 138-47.

³⁴ U. S. Bur. Pl. Ind., Bull. 230 (1912), p. 72.

COMPARISON OF CHEMICAL DATA

The total nitrogen content of the samples of each type varies within somewhat wide limits. The average amounts for the several types are distinct, though the variations are such that some of the quantities of one type overlap those of another type. It is believed that for the types selected the field differentiations do indicate differences.

Regarding the humus content of the four types under consideration, the results are somewhat different. The average amounts of humus are almost alike in three of the four types, while the nitrogen-poor San Joaquin soil has an average of about half that of the others. Within the type the soils may be very nearly alike in the humus content, as is the case in two of the types, or may be widely variable, as in the Hanford fine sandy loam. It should be noted that the amount of humus as shown by the method used, is not indicated by the intensity of the color either of the soil or of the resulting extract. This confirms the findings of Gortner, which are cited elsewhere.

There was quite a wide range shown in the results of the determination of the loss on ignition. The Diablo and Altamont soils, because of the heavier textures and the relatively large amounts of combined water, and of considerable amounts of CaCO_3 , in at least one case, gave high losses on ignition. The averages were close, 6.8% for the Diablo, and 6.7% for the Altamont. The Hanford soils were lower, though with a wider range. Soil no. 14, with 6.9% loss on ignition, shows almost double that of any other soil in the type. The San Joaquin soils, with an average of 2.6%, show the lowest average loss on ignition. The smaller amounts of organic matter in these soils is one reason for the smaller loss. The two heavier types have averages close together, and the lighter types have averages not far apart, but because of the wide variations within each type, the results of the determination of the loss on ignition certainly do not show that all soils classified in one type are closely similar.

Hall and Russell, in their discussion of the soils of southeastern England,³⁵ consider of value the ratio of $\frac{\% \text{ total nitrogen}}{\% \text{ loss on ignition}}$, but applying this ratio to the California soils under consideration does not seem to give any relations of value. The Diablo ratio varies from 0.0136 to 0.0158, the Altamont from 0.0141 to 0.0204, the San Joaquin from 0.0144 to 0.0232, and the Hanford from 0.011 to 0.0172.

³⁵ Jour. Agr. Sci., vol. 4 (1911), pp. 182-223.

The calcium (as CaO) content of the soils is interesting especially because of the variability. The Altamont samples show the greatest variation, for the largest quantity of CaO is about seven times the smallest. The San Joaquin samples are second, with the largest over six times the smallest. The Diablo samples are third, with the largest over five times the smallest, while the Hanford soils show the least variation, the largest being less than twice the smallest. There are quite marked differences between the averages of the Diablo, Altamont, and Hanford soils (the San Joaquin samples are intermediate), but the wide variations within the types greatly minimize any significance the averages might have. Hence it is not possible to state that one or another type, as represented by these samples, is characterized by high, low, or moderate amounts of calcium.

As the analyses of the samples for calcium failed to point out any striking characteristics, unless it be that of variability, so it is with magnesium. Magnesium (as MgO) is variable within each of the four types. The largest quantity is about three times the smallest in the Diablo, San Joaquin, and Hanford types, while in the Altamont the largest is twenty-seven times the smallest. Considering the Hanford and San Joaquin, or the Diablo and San Joaquin, it is seen that the curves do not overlap, while the Diablo and Altamont, or the Diablo and Hanford curves do. The averages of the four types are distinct, except between the Hanford and Diablo, which are quite close. But, here again, because of the more or less wide range of values within each of the types, the averages are of little significance. The lime-magnesia ratio is very variable in these soils. Comparing the calcium and magnesium curves for the several soils gives a good idea of the relations. The Diablo curves are quite similar except for soil no. 6, which shows 3% MgO and 0.5% CaO. In the Altamont soils the curves are somewhat similar in direction, though the ratios differ widely. In the Hanford and San Joaquin types the ratios of CaO and MgO are also far from constant, yet it is readily seen from the graphs that the amount of magnesium varies more or less directly with the amount of calcium.

Respecting the total phosphorus (as P_2O_5), if the San Joaquin and Hanford samples alone be considered, there would be no doubt as to the significance of the field separation, the variations within the type notwithstanding. But when the other two types are considered, the case is not so good in favor of the field classification. The Diablo soils show considerable variation in the amount of P_2O_5 , while the three

Altamont samples show much variation. Therefore with reference to the amount of phosphorus, and the types studied, the separation into types may or may not be of significance.

If the results of the potassium (K_2O) determinations are compared, it is very evident that but one conclusion can be drawn, and that is that the variations in the amount of potassium within each type are great enough so that any differences between the averages of the several types have no significance whatsoever. Therefore, with regard to total potassium the field separation of soils as represented by these twenty-four samples of four types means nothing.

COMPARISON OF BACTERIOLOGICAL DATA

The wealth of the data obtained from over nine hundred bacteriological tumbler cultures is hardly of sufficient significance to compensate for the effort involved. There is one outstanding conclusion from all this work, namely, the lack of any very definite, distinct, and constant bacteriological activity of the samples of one type that is not to a considerable extent shared by the samples of the other types. There are tendencies in certain types with regard to bacteriological activity which show that some of the types as a whole are more or less distinct from one or more of the others.

Ammonification.—The amount of ammonia produced from dried blood varies to a great extent. The Altamont samples gave between 10 and 33 mg. nitrogen as ammonia; the Diablo samples gave between 7 and 26 mg., and the Hanford samples gave between 35 and 72 mg. The Altamont and Diablo types are thus seen to be about alike in their low ammonifying power, as compared with the higher ability of the San Joaquin types and still greater ability of the Hanford types. And since there are somewhat greater variations between the types than between the samples of a given type, the ammonifying power may be significant.

Nitrogen fixation.—The two heavy types, Diablo clay adobe and Altamont clay loam, show no characteristic differences, while the two lighter types show considerable differences. As a whole the types are different one from another, yet the variations within the type are sufficient to prevent any statement that the rate of nitrogen fixation is a function of the type as determined in the field, or vice versa.

Nitrification.—The nitrification data are the most puzzling. The figures are extremely variable within a given type; the erratic way

in which the Hanford samples behave is not paralleled by any other type. There are certain ways in which the types are distinct:

The nitrification of the soil's own nitrogen as compared with the soil's action upon added nitrogen is in some degree separate for each type. The San Joaquin samples nitrified their own nitrogen to a greater degree than they did the nitrogen added to the soil.

The relative nitrification of the several nitrogenous materials (dried blood, cottonseed meal, ammonium sulfate) is in some measure distinct for the several types. The Diablo, Altamont, and San Joaquin types show ammonium sulphate to be nitrified the best, cottonseed meal less, and dried blood still less. The Hanford samples show cottonseed meal to give the highest percentage of nitrates, with dried blood less, and ammonium sulfate still less.

When any one soil is compared through the three sets of determinations there are no apparent similarities. The Hanford type shows the greatest bacterial activity, while the San Joaquin shows less, with the heavier types showing sometimes greater activity and sometimes less than that of the San Joaquin.

WORK IN OTHER STATES

In connection with the original chemical work reported in this paper, there should be mentioned the large amount of work done in a number of states on the analysis of the types of soils as mapped by the Bureau of Soils. Apparently, these analyses have been made without any question as to the validity of the existing subdivisions into types. The various analyses have been reported with some comment, but that which does appear usually deals with the "adequacy" or "inadequacy" of the plant food present. Blair and Jennings³⁶ present a large amount of data on chemical composition, some of which on rearrangement show interesting relationships (table 85). From the data the four series of soils with the largest number of analyses were selected (see following table). Under each series there are from 2 to 4 soil types, and from 2 to 6 analyses under each type. The averages from each type are tabulated, also the averages of all the types within the series. This is both for the strong acid extraction and the fusion methods of analysis for significant plant food elements. There are no doubts but that each series of soils shows characteristic chemical peculiarities, peculiarities which are to a great extent con-

³⁶ The Mechanical and Chemical Composition of the Soils of the Sussex Area, New Jersey, Geol. Surv. N. J., Bull. 10, 1910.

TABLE 85

	Dutchess				Dover				Gloucester				Chenango				Dutchess	Dover	Gloucester	Chenango
	Loom 6	Loom (stacey phase)	Shade loam 5	Loom 3	Loom (light phase) 2	Stony loam 3	Loom 5	Sandy loam 3	Stony loam 4	Stony sandy loam 4	Stony sandy loam 2	Loom 2	Loam 2	Loam 2	Loam 2	Loam 2				
Insoluble	2.82	80.07	75.95	86.93	86.87	86.66	84.55	84.00	84.19	84.11	89.53	89.74	.....	.....	.....	.....	.....	.....	.....	.....
SiO ₂	.05	.062	.06	.05	.065	.033	.05	.03	.07	.04	.07	.06	.....	.....	.....	.....	.....	.....	.....	.....
K ₂ O	.28	.315	.34	.203	.13	.170	.21	.14	.205	.13	.125	.265	.31	.17	.17	.17	.17	.17	.17	.19
Na ₂ O	.083	.057	.074	.07	.055	.057	.08	.10	.11	.11	.10	.110	.071	.061	.10	.10	.071	.061	.10	.10
CaO	.08	.107	.13	.13	.24	.153	.26	.45	.19	.35	Tr.	.10	.106	.174	.31	.10	.106	.174	.31	.05
MgO	.68	.910	1.00	.51	.61	.510	.64	.52	.57	.43	.45	.465	.....	.....	.....	.....	.....	.....	.....	.....
Mn ₂ O ₃	.04	.065	.05	.06	.045	.015	.06	.07	.03	.06	.045	.07	.....	.....	.....	.....	.....	.....	.....	.....
Fe ₂ O ₃	3.05	3.91	4.49	2.67	2.83	2.32	2.50	3.76	2.99	3.68	1.96	2.42	.....	.....	.....	.....	.....	.....	.....	.....
Al ₂ O ₃	4.96	5.70	6.73	3.09	3.57	3.89	4.22	3.79	4.01	4.20	3.99	3.06	.....	.....	.....	.....	.....	.....	.....	.....
P ₂ O ₅	.135	.186	.137	.113	0.46	.077	.109	.156	.126	.152	.139	.114	.153	.217	.136	.114	.153	.217	.136	.126
SO ₃	.065	.06	.....	.....	.....	.040	.06	.045	.....	.06	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
CO ₂	.038	.034	.053	.025	.035	.035	.04	.075	.054	.05	.023	.042	.....	.....	.....	.....	.....	.....	.....	.....
Volatile	7.67	6.21	11.06	6.21	5.32	6.117	7.27	6.15	7.44	6.61	4.54	3.73	.....	.....	.....	.....	.....	.....	.....	.....
Totals	N	.161	.173	.145	.138	.112	.150	.131	.174	.139	.094	.085	.....	.....	.....	.....	.....	.....	.....	.....
	C	1.82	1.877	2.43	1.54	1.45	1.59	1.31	2.27	1.72	1.175	.854	.....	.....	.....	.....	.....	.....	.....	.....
	K	1.44	1.68	1.606	2.46	2.75	2.58	3.06	2.22	2.53	.96	1.30	1.57	.233	.259	1.30	1.57	.233	.259	1.13
	Na	.....	.....	.....	.60	.98	.50	1.43	.186	1.27	.82	.655	.65	.69	1.59	.65	.69	1.59	.65	.65
	P ₂ O ₅	.16	.215	.157	.134	.168	.091	.129	.175	.143	.165	.131	.17	.13	.15	.131	.17	.13	.15	.15

stant throughout the several representatives of the type. In some cases, the differences or similarities are more clearly seen in the total analyses, and in other cases, they appear in the acid analyses and not in the fusion analyses. Within any series the variations between analyses of any one type are about the same as the variations from type to type. There are many other papers³⁷ which provide material for similar comparisons.

A paper by Van Dyne and Ashton³⁸ reports chemical analyses for lime, phosphoric acid, potash, and nitrogen on the samples collected in the course of the survey of Stevens County, Washington. Though sometimes there is a much greater range within a type than between types, in a general way the analyses for any one type agree quite well. As a whole the chemical analyses seem to show that the field criteria are also a basis for grouping soils into certain chemical groups. It should be mentioned that the work of Blair and Jennings, also that of Van Dyne and Ashton, deals with individual areas, and not with samples from several scattered areas. The work of Fraps and Williams, and the original work here reported represent scattered areas.

THE GREENHOUSE CULTURES

By far the most interesting results were obtained in the pot culture work. It is realized that there are variations in the physical nature of the samples of a given type, yet since these samples were collected with considerable care by one familiar with field classifications, the samples so selected should be fairly representative of the type. It is probable that if all the soils in each of the types used were exactly the same in texture, i.e., if the mechanical analysis showed the same results for the several soils, the crops produced on the several soils of a type would be less divergent in appearance or weight. Yet it is not at all likely that the crops would be the same. Pot cultures presume that the conditions in all the pots can be kept uniform, but this is obviously impossible. Greenhouse work is subject to many interfering factors. Nevertheless, the results are believed to be significant,

³⁷ Williams, and others, Report on the Piedmont Soils, North Carolina Dept. Agr., Bull. 206, 1915.

Fraps, G. S., Composition of the Soils of South Texas, Texas Agr. Exp. Sta., Bull. 161, 1913; Composition of the Soils of the Texas Panhandle, *ibid.*, Bull. 173, 1915.

³⁸ Van Dyne and Ashton, Soil Survey of Stevens County, Washington, Field Operations, U. S. Bur. Soils, 1913, pp. 2165-2295.

despite the large correction that the consideration of the probable error might introduce.

The differences in the crop producing power of the soils are very marked in the Diablo clay adobe, where the second crop, as well as the first, shows evident variations in the ability to support a crop. In the Altamont clay loam the second crop almost loses the variations seen in the first crop from pot to pot. The samples of both types seem to show one thing in common—the approach of the several samples toward a uniform ability to produce crops, as the soils are kept for longer periods under the same conditions. The Hanford soils did not show, with the several crops, the parallelism in the fertility from crop to crop as did the Diablo and Altamont soils. Some soils produced good crops of grain and poorer crops of legumes, others did the opposite. The low nitrogen content in this type seemed to be a limiting factor. This would account for the variation between the grain and the leguminous crops. Also, the presence, or absence of *Bacillus radicuola* inoculation in this connection might greatly affect the total crop produced.

There does not seem to be much doubt but that the soils of the several types compared in this way are not the same, though they are in certain respects similar.

The Place of Soil Classification.—With all these evidences that the soils within the several types are not closely similar, though they are classified the same by the Bureau of Soils, what conclusion is one to reach as to the value of such a classification? If it were true that there were no appeal from the findings of such laboratory and greenhouse determinations as these, and that these determinations were a final proof of the fertility or infertility of a soil, obviously there would be but one thing to do—discard all such field classifications as useless. But the writer is one of a great many soilists who are not willing to rely on laboratory or even greenhouse results for an *absolute* determination of fertility, and for the grouping together of soils into a workable classification. Not enough is definitely known as to the meaning of such findings, though there are certainly many valuable points shown by laboratory analyses.³⁹

As examples of the value of natural classifications we may consider those of botany, zoology, or mineralogy. If available, a wholly satisfactory classification of soils would be equally useful. The appre-

³⁹ Jordan, W. H., Measurements of Soil Fertility, New York Agr. Exp. Sta., Geneva, Bull. 424, 1916.

ciation of this is shown in the many systems of soil classification that have been proposed.

Despite the foregoing facts that have been obtained showing the divergent properties of different samples of one type presumably alike, yet it must be admitted that soil surveys, even such as are no more refined than those of the Bureau of Soils, have considerable value for field use.

It is felt that the additional effort required to modify the practices of the Bureau of Soils in the mapping and classifying of soils would be more than justified by the increased accuracy and usefulness of the maps. To point out some of the causes of the present practices and to give suggestions for possible methods of improvement, the following discussion of the Bureau of Soils methods has been prepared.

Discussion of the Bureau of Soils' methods.—The methods of mapping and classifying soils, as devised and used by the Bureau, have resulted from some definite and important considerations.

1. The necessity for keeping down the cost of surveying and mapping prevents the use of laboratory and culture methods in the study of the soils classified, even if it were not for the fact that one of the outstanding policies of the Bureau apparently denies the validity of such studies in the classification of soils. This does not include the mechanical analysis of soils, which is not a separate laboratory determination, but a method of checking the field man's decision as to the texture. It should also be added that some of the reports as published in the Field Operations of the Bureau of Soils, for 1913, show the subdivision of the soils into two groups based upon the CaCO_3 content. Keeping down the cost has also prevented the use of sufficient time to map the soils correctly, even according to the criteria admittedly of value in the system adopted. Many of the other methods of classifying and mapping soils, even if applicable to most of the agricultural regions of the United States, would be absolutely out of the question on account of cost.

2. The large and widely diversified area of the United States, and the attempt to map representative areas in various parts of the country, early led to difficulties. There seemed to be a lack of understanding as to what criteria to use in the classification of the soils. Recently, some of the areas first mapped in the state of California have been resurveyed. The texture, series, and province differences of the early mapping seem not to have been clear. For example, we may con-

sider the differences between the older and the recent survey of two localities east of Los Angeles. The notes were made by C. J. Zinn, a member of the party which made the recent survey:

Locality A—About 15 square miles with Eaton Wash on the west, center of Monrovia on the east, mountains on the north, and a line about 3 miles south of mountains as the south boundary. The old survey⁴⁰ has four types of three series and two miscellaneous types: San Gabriel gravelly loam, San Gabriel gravelly sand, Placentia sandy loam, San Joaquin black adobe, and Riverwash and Mountains. The new survey (1915, unpublished) has 13 types of 6 series and 3 miscellaneous types: Hanford stony sand, gravelly sand, loam, sandy loam, fine sandy loam, and sand; Tejunga stony sand; Zelzah loam and stony loam; Placentia loam, Holland loam, Chino loam and silt loam. The miscellaneous types are Rough Mountain land, Rough Broken land, and Riverwash.

Locality B—In the city of Pasadena, comprising about 3.5 square miles, with the southwest corner at the center of the city. The old survey⁴¹ shows San Gabriel loam occupying about 0.6 of the area, San Gabriel gravelly sand about 0.3, and Placentia sandy loam about 0.1. The new survey (1915, unpublished) shows Zelzah gravelly loam occupying about 0.9 of the area, Zelzah loam about 0.1, with a very small body of Holland loam. The older survey showed a recent alluvial soil where the recent one shows an old valley filling soil.

Besides these errors (detected as such by the practical man, who might attempt to use the soil maps in the field) there are in addition those of another nature which were the source of much criticism in the earlier history of the survey—the so-called “procrustean classification” criticism of Hilgard.⁴² Due apparently to an insufficient study of the soils of the United States, there was the attempt to classify in the same series soils of widely differing properties—differences of an important nature being ignored.

At the present time there is an increasing tendency toward limiting series groups of soils to a more or less definite climatological region. In this connection see the later changes in the correlation of many soils.⁴³ These changes tend to limit the geographic range of the series, and make these series narrower and more exact. Moreover, it is understood that as the knowledge of the soils has increased, the changes in correlation have been proceeding rapidly since the above list was issued. This indicates that as the facts accumulate the “procrustean classification” criticism is losing its force.

⁴⁰ Field Operations of the U. S. Bur. of Soils, 1901, San Gabriel sheet.

⁴¹ *Ibid.*

⁴² Hilgard, E. W., and Loughridge, R. H., Proc. Second Intern. Agrogeol. Conf., Stockholm, 1910, pp. 228-29; Hilgard, E. W., U. S. Office Exp. Sta., Bull. 142 (1904), p. 119; Hilgard, E. W., Proc. First Intern. Agrogeol. Conf., Budapest, 1909, pp. 52-54.

⁴³ U. S. Bur. Soils, Bull. 96, 1913.

3. There was a lack of trained men early in the work. This was to be expected. As has been shown, the early surveys were very crude in certain places. It must be added that some of the errors and omissions made in the more recent maps are not due to a lack of training, but to the carelessness of the field men with respect to details.

4. The policy of the Bureau has been to recognize the physical characteristics of the soil as factors in fertility to the virtual exclusion of the chemical or biological factors. Therefore the use of physical criteria is necessary. Besides, the criteria must be such as can be applied in the field, and are: (1) color, (2) texture, determined by rubbing between the thumb and finger, (3) structure, (4) nature of subsoil, (5) presence of hardpan, (6) height of water table, (7) presence of alkali, (8) topography, (9) physiographic form and hence mode of formation, and (10) source of material (sedimentary, igneous, or metamorphic rocks). Humus, and the presence or absence of appreciable quantities of lime, also the reaction of the soil (acid or alkaline) are frequently guessed at. These criteria are practically the only ones that can be applied in field work. It is believed that these same criteria indicate the chemical nature of the soil, though there has been no attempt to correlate some of the factors. However, the original work reported in this paper would indicate that the chemical nature is not the same, of soils classified the same by the Bureau of Soils criteria.

5. The desire to limit the number of groups of soils is a wholly sound one. In discussing the problems of classifying soils there should always be kept in mind the fact that some of the problems are not very different, fundamentally, from some of the problems that have been causing perplexity among biologists for a long while. The tendency, as seen in some of the recent surveys, to make the series more inclusive and to introduce the term, phase, is heartily commended. By making the series broader there will be less difficulty in placing a soil in its proper group. The phase will take care of many of the series differences between area and area.

6. It seems certain that if there were more emphasis placed upon the inspection of the area, during the progress of the field work and after its completion, there would be a much closer approach to accuracy throughout the map and report. At the present time the field man is not closely checked up. The careless or indifferent worker can map more or less as he pleases, especially in the out-of-the-way places.

7. Whether the soil survey should include more than a simple classification of the soils or not, is an unsettled question. It is thought hardly possible that in a soil survey the field man could handle all the phases of an agricultural survey of an area, when his energies should be fully employed in the classification of the soils. It is believed that the place of the survey, in this country at least, is to handle the *classification* of the soils, leaving the study of the remaining factors largely to other specialists, who would use the soil survey as a basis.⁴⁴ But to make the soil maps of more general use for such work, they must be more accurate. These maps never can become the basis of other agricultural studies as long as many experiment station workers ridicule them. Hence, the ultimate effort of the survey should be toward better work, rather than covering a wide range of agricultural studies.

8. There is not the incentive to make as many separations of the soils in the field, as the field man might think best, because frequently the feeling of the editors is that there would be too many small bodies of soil shown on the manuscript maps which would not warrant the additional cost of publication.

In conclusion, the Bureau of Soils' system has much to commend it as a field method, and the resulting maps and classification are believed to be of distinct value. It is felt that a more general understanding of: (1) the limitations under which the maps, the earlier ones especially, have been made; (2) the difficulties under which the field work is at present carried on; (3) the meaning of the correlation of soils; and (4) the general policy of the Bureau of Soils would give people more sympathy with their work.

⁴⁴ Fippin, E. O., Proc. Amer. Soc. Agron., vol. 1 (1908), pp. 191-97.

SUMMARY

Presumably typical samples of four soil types were collected for laboratory and greenhouse study from widely distributed localities in the state of California. The field appearance of each sample was usually sufficient to warrant the classification as it exists.

PHYSICAL RELATIONS

1. The mechanical analysis by the Hilgard elutriator shows that the soils of a given type are in some cases quite divergent from each other in their content of certain of the sizes of particles. The mechanical analysis by the Bureau of Soils method shows that 6 of the 24 soils were not true to their type names, and that of those soils within the type there is considerable variation.

2. The moisture equivalents for the several types show distinct enough values to substantiate the field separation.

3. The hygroscopic coefficients vary widely within each type and the types are not shown to be distinctly different by this criterion.

CHEMICAL RELATIONS

1. The total nitrogen averages vary markedly from type to type, with the Altamont clay loam containing three times that in the San Joaquin sandy loam.

2. The average humus content of the San Joaquin samples is about half that of the other types. The variations in the humus content between the types are small, considering the diverse nature of the types and the large range in the amount of humus within the type.

3. The loss on ignition shows a considerable variation within the type and no significant distinction between the four types.

4. The average total calcium content of the types is distinct, though the wide range within each type minimizes the significance of the variation in the averages.

5. With regard to magnesium, the types are neither distinct nor are the soils within the type closely similar.

6. The average phosphorus content of the types is distinct, though the ranges within the several types frequently overlap.

7. The total potassium results do not show the types to be distinct nor the soils within a type closely similar.

BACTERIOLOGICAL RELATIONS

1. The ammonifying power shows rather larger variations from type to type than between the samples of a type.

2. The nitrogen fixation data do not show characteristic differences for the several types.

3. Regarding nitrification as a whole there may be a greater divergence between the samples of a type than between types. The relative nitrification of the soil's own nitrogen varies with the type, as does the relative nitrification of the several nitrogenous materials added.

POT CULTURES IN THE GREENHOUSE

In addition to the effect of the probable error, the impossibility under the conditions herein described of growing the same crops on all the soils, during the same season of the year in the greenhouse, prevents close comparisons between the types, or between the first and second crops on a given soil. The comparison of several samples of a given soil type and the comparisons of various soil types, according to the previously outlined greenhouse methods show that:

1. Different representatives of a given type are not the same in their ability to produce crops.

2. The arrangement of the samples of a given type according to their fertility may or may not vary with the special crops used as the indicators.

3. The types are distinct with respect to their fertility, considering their average production.

Therefore it is concluded that with regard to the 24 soils of 4 types examined, all soils mapped under a given name by the Bureau of Soils method may or may not be closely similar, depending upon the criteria used. The greater number of the criteria show the soils of a type to be not closely similar, and the types to be but little differentiated from each other.

In connection with the results of the author's study of the soils, there is given an historical sketch of the development of soil classification and mapping, also a discussion of certain of the methods employed by the Bureau of Soils of the United States Department of Agriculture. It is pointed out that despite its defects, the work of the Bureau of Soils is of value, and is practically the only type of soil classification and mapping possible under the conditions imposed.

APPENDIX A
METHODS AND TECHNIQUE

COLLECTION OF SAMPLES

There was difficulty in finding types that would meet the requirements of wide distribution and of differing from one another as to series as well as texture. The types chosen were:

Diablo clay adobe, a residual soil.

Altamont clay loam, a residual soil.

San Joaquin sandy loam, an "old valley filling" (old alluvial soil).

Hanford fine sandy loam, a recent alluvial soil.

The first task was the collection of the samples of soil for study in the laboratory and in the greenhouse. Of course, there were kept in mind the errors and difficulties involved in the collection of representative samples. The selection of the localities in which to collect samples was frequently made in consultation with the persons who had originally mapped the areas under the Bureau of Soils. This was done so that the soil chosen might as nearly as possible represent what the surveyor had in mind as characteristic of the type within the area. It was to be expected that the ideal type which one man would use as a guide as he did the mapping in one area would not always be identical with that which another man might use in mapping another area, despite the aid of the inspector in keeping the ideal types of the field men as nearly alike as possible. Some of the accompanying index maps, showing the places where the soil samples were collected, are duplicates of the same locality. As the dates show, one is a portion of a less recent, and the other of a more recent survey. In many cases the index maps have been copied from the manuscript maps, a number of surveys in this state not yet being published. For a discussion of the differences in these maps, see below the section on The Criticism of the U. S. Bureau of Soils Method of Surveying.

Not only were the field men questioned about the locality, but as nearly as possible an exact designation was obtained on the soil map itself. In the collection of some of the samples the writer had the good fortune to have the assistance of the man or men who actually mapped the soils in question. Sometimes there was no trouble at all in locating a typical body of the soil where a sample might be taken. On the other hand, as in the case of the collection of the Hanford fine sandy loam from Woodbridge (nos. 15 and 16), more than two hours were spent in driving about, trying to find a place that seemed a typical fine sandy loam. Experience shows that the personal equation in field work is very important and is hard to control.⁴⁵

No special attempt was made to obtain virgin soil, for the types of soils that had been selected for study were mainly agricultural, and most of the soils have been at some time under cultivation, if they are not now. Also, there has been little, if any modification of the agricultural soils by the addition of fertilizers. Hence the small tracts of the Hanford fine sandy loam, for instance, that are still virgin are largely non-agricultural, waste land areas, and would not illustrate the properties of the type as a whole. Not so large a part of the San Joaquin sandy loam is under cultivation now, though almost all of it has been farmed to grain in the past. The two minor types studied, the Altamont clay loam and the Diablo clay adobe, being of residual origin and occupying rolling to hilly or mountainous land are also not very extensively farmed. The topography is the limiting factor in most cases.

⁴⁵ Fippin, E. O., *Practical Classification of Soils*, Proc. Amer. Soc. Agron., vol. 3 (1911), pp. 76-89; *Increasing the Practical Efficiency of Soil Surveys*, Proc. Amer. Soc. Agron., vol. 1 (1907-1909), pp. 204-06.

The ideal way to collect a representative sample of soil for laboratory studies is to make a number of borings scattered about the field or fields, so that the sample will approximate an average. But in the case of collecting the samples for this study it was considered best not to attempt such a procedure, for the reason that it was desired to have the samples for the greenhouse work and for the physical, chemical, and bacteriological studies, come from the same lot of soil. The collection of such a large amount of soil, about 250 pounds in all, from a number of places about the selected field would be very tedious. Hence as nearly a typical place as possible was selected, close to a wagon road, in order that the samples could be transported readily. Care was used that the location be far enough out into the field to allow the sample to be representative of the conditions in the field.

The subsequent procedure was as follows: The selected spot was cleared of grass or other surface material or accumulation that did not belong to the soil. A hole was dug, usually one foot deep (the depth depending entirely upon the nature of the surface soil and any noticeable changes toward the subsoil), and big enough to give sufficient soil to make up the greenhouse sample of from 225 to 250 pounds. The soil was shoveled directly into tight sugar or grain sacks, no attempt being made to mix the sample at this time. Some sacks of the soil would contain more of the surface material, and others more of the lower portion, but a later thorough mixing and screening at the greenhouse gave a uniform sample. After the large sample was collected, the hole was usually dug two feet deeper, giving a hole three feet deep. One side of this hole was made perpendicular, and from this side the small samples were collected. The A, B, and C horizons were marked off on this wall, and the samples collected by digging down a uniform section of the designated portion, using a geologic pick and catching the loosened material on a shovel. About ten pounds of soil were so collected, and placed in clean, sterile canvas sample sacks. Care was used not to contaminate the samples, so that the bacterial flora might remain nearly unaltered. It seemed impracticable to attempt to collect the laboratory sample under absolute sterile conditions, especially since some of the deeper (B and C) samples were obtained by means of the soil auger. When the auger was used to collect the samples from greater depths the boring was done from the bottom of the hole made in collecting the larger sample. The size of the laboratory sample required the boring of five or six holes with the usual 1.5 inch soil auger. The laboratory sample of the first foot, or the A sample, was always collected from the side of the large hole. Notes regarding the sample, field condition, the place of collection, together with photographs and marked maps are given in appendix B.

As described above, the soils were collected in separate portions from the surface to the 12 inch, from the 12 to 24 inch depth, and from the 24 to 36 inch depths where there were no abrupt or marked changes in the color, texture, or the like, as in the Hanford fine sandy loam. But since in some cases, as most frequently in the San Joaquin sandy loam, the samples do not represent the first, second, or third foot depths, as the case might be, the term, horizon, has been used. Horizon A indicates the surface sample, horizon B the second sample, and horizon C the third sample.

LABORATORY PREPARATION OF SAMPLES

The large samples were stored in the greenhouse until ready for use. The laboratory samples were allowed to remain in the sacks until air dry, when they were passed through a 2 mm. screen. This was a difficult matter, with the heavy soils, as well as with the heavy subsoils of the San Joaquin sandy loam. Cautious use

of the iron mortar was necessary to supplement the rubber pestle.⁴⁶ The samples were thoroughly mixed after screening, when they were weighed and placed in sterile containers—glass jars and large bottles. Precautions were taken as far as possible to avoid contamination of the samples during this preparatory process. The screens, mortars, scoop, and pans were flamed out between samples. Obviously contamination could not be avoided absolutely without too great a prolongation of the work.

The material not passing the 2 mm. screen was subsequently washed on the screen, with a stream of water to remove the finer material. The residue not passing the screen by this treatment was dried and weighed. It seemed unnecessary to adopt elaborate precautions, like those described by Mohr,⁴⁷ to obtain the exact quantities.

MECHANICAL ANALYSIS

The Hilgard elutriator was used for the purpose of making the mechanical analysis of the samples (surface horizon only). For the purpose of this work the method described by Hilgard⁴⁸ has been modified in several respects. The preliminary preparation by sifting through the 2 mm. sieve in the dry state, and through the 0.5 mm. sieve by the aid of water was used. One hundred grams was sifted with the 0.5 mm. sieve, and the fine material plus the water was evaporated to dryness on the water bath. The dry material was broken up and from this the samples were weighed out for the analysis.

The samples were not disintegrated by boiling, since it was believed that such treatment would affect the "colloid" content of the sample. Instead, the samples were shaken with water in sterilizer bottles for three hours, similar to the treatment preparatory to the mechanical analysis by the Bureau of Soils method. However, not boiling the samples caused more work later.

The colloidal clay was removed by placing the previously shaken sample in a large precipitating jar and stirring up with several liters of distilled water. (Distilled water was used throughout the analysis.) The quantity of water was not important, but rather the depth of the suspension, which was 200 mm. After allowing to stand for 24 hours the supernatant turbid water was siphoned off, when the residue in the bottom of the jar was again stirred up with water and the clay again allowed to settle out of a 200 mm. column. This was repeated until the supernatant liquid contained practically no material in suspension after standing for 24 hours. The clay suspensions were placed in large enamelware preserving kettles, and the solutions reduced in volume by boiling. The final evaporations were carried on over the water bath, so as to avoid too high a temperature.

A large portion of the finest sediment (0.25 mm. hydraulic value) was removed as follows: After the greatest portion of the clay had been removed by the 24 hour sedimentation and decantation, the sample was placed in a 1 liter beaker and stirred up with sufficient water to make a 100 mm. column. After standing 6 to 8 minutes the suspended material was decanted off. This was repeated until the supernatant solution was practically clear. The entire time for these decantations usually occupied 2.5 or 3 hours. The decanted material was allowed to stand for 24 hours, as before, and the 200 mm. column decanted as with the original clay suspension. This was continued until the clay was practically all removed.

⁴⁶ Hilgard, Calif. Agri. Exp. Sta., Circ. 6, June, 1903.

⁴⁷ Bull. Dept. Agr. Indes Neerland., no. 41, 1910.

⁴⁸ Calif. Agr. Exp. Sta., Circ. 6 (1903), pp. 6-15; see also Wiley, *Agricultural Analysis*, vol. 1 (1906), pp. 246-62.

The residue constituted the main portion of the 0.25 mm. hydraulic value separate. The residue from the 6 to 8 minute decantation was placed in the elutriator, and separated by the usual method into the various sizes. Since, however, the sample was not prepared by boiling previous to the separation of the clay, the clay was never as thoroughly removed from the coarser particles and the finer aggregate particles were not completely broken down. Hence when the sample was placed in the elutriator and subjected to the violent agitation of the stirrer an appreciable amount of clay passed off with the finest separate. Therefore, instead of allowing the water to return to the carboy from the settling bottle, during the running off of the finest separate, the following procedure was employed: The water was run into precipitating jars and allowed to stand for 24 hours, and the clay water was then decanted off and boiled down with the other clay water.

A further modification of the Hilgard method was found advisable after the change from the large elutriator tube to the small one, preparatory to running off the coarser separates. The mechanical defects in the elutriator always allowed for the collection of a portion of the sample in crevices where the stream of water could not reach to carry off the particles. Hence, when the large tube was removed, and cleaned, there was found an appreciable amount of the finer sediments that had not passed over. These were all added to the small tube of the elutriator, and the additional material of the smaller sizes run off, using an hour or so for each size. This seemed a better method than the separation of such sediments by the beaker method, as was done by Dr. Loughridge.

The separates, after decanting most of the water, were dried first on the water bath and later in the drying oven at 100°C–110°C and weighed. All of the determinations were made on the water free basis.⁴⁹

ADDITIONAL PHYSICAL DETERMINATIONS

Upon the surface or A horizon samples of the 24 soils considered in this study additional physical determinations were made by the Division of Soil Technology, through the courtesy of Professor Charles F. Shaw. These determinations were of the mechanical analysis by the Bureau of Soils method,⁵⁰ of the moisture equivalent by the Briggs and McLane method,⁵¹ and of the hygroscopic coefficient according to Hilgard's method.⁵²

CHEMICAL METHODS

At first the chemical work was based upon the "strong acid extraction" method, so well known through the work of Dr. Hilgard.⁵³ There are some very pertinent objections, as well as advantages, to the method of acid extraction for the purpose of comparing soils among themselves.⁵⁴

In the analysis 2.5 gram samples, air dry, were used throughout. The acid extraction results are not included in this paper.

⁴⁹ The writer wishes to emphasize the tedium of the elutriator process, and to advise strongly against the use of the apparatus for the comparison of the soils as to texture. The elutriator is excellent from a theoretical point of view, but the results do not at all warrant the extravagant use of time in the laboratory that the apparatus requires.

⁵⁰ U. S. Bur. Soils, Bull. 84, 1912.

⁵¹ *Ibid.*, Bull. 45, 1907; Proc. Amer. Soc. Agron., vol. 2 (1910), pp. 138–47.

⁵² Calif. Agr. Exp. Sta., Circ. 6 (1903), p. 17; Soils, pp. 197–99.

⁵³ Calif. Agr. Exp. Sta., Circ. 6 (1903), pp. 16ff; Soils, pp. 340ff.

⁵⁴ See Hissink, Intern. Mitt. für Bodenkunde, vol. 5 (1915), no. 1.

The sodium peroxide fusion method⁵⁵ was carried out on the two larger series of soils, the Hanford and the San Joaquin. The elements sought were phosphorus, calcium, and magnesium. Five gram samples, air dry, were used throughout. The general method of analysis, as set forth by Hopkins, was employed, though there were a number of refinements used to increase the accuracy of the results. As such might be mentioned the double precipitation of the iron, aluminum, and phosphorus.

Phosphorus was determined volumetrically, according to the method of Hibbard.⁵⁶

Total nitrogen was determined by the modified Gunning-Kjeldahl method, using ten gram samples.

Loss on ignition was determined upon the 10 gram, air dry samples that were used for the determination of the hygroscopic moisture of the samples used in the chemical analysis. The soils were ignited in a muffle furnace to constant weight.

Humus was determined by the Grandeau-Hilgard method,⁵⁷ using 10 gram samples, air dry.

Potassium was determined by the J. Lawrence Smith method, using one gram samples.

BACTERIOLOGICAL METHODS

The only bacteriological methods employed were the determination by the tumbler or beaker method of the ammonifying, the nitrifying, and the nitrogen fixing powers of the soils.⁵⁸ All cultures were run in duplicate.

Ammonification tests were made using 50 grams of soil and 2 grams (4%) of dried blood. The checks were distilled at once, and the cultures kept in the incubator at 24°C–30°C for one week. (The incubator thermostat was unsatisfactory in its action, hence the variation in the temperature.)

The nitrifying power of the soil was tested as regards the soil's own nitrogen, dried blood, cottonseed meal, and ammonium sulfate. In the Diablo clay adobe and the Altamont clay loam 50 grams of soil were used, to which was added 1 gram (2%) of dried blood, or of cottonseed meal, or 0.1 gram (0.2%) of ammonium sulfate. In the case of the San Joaquin sandy loam 50 grams of soil were used, together with 1 gram (2%) of dried blood or of cottonseed meal, or 0.2 gram (0.4%) of ammonium sulfate. In the series run on the Hanford fine sandy loam 100 grams of soil were used, to which were added 1 gram (1%) of dried blood or of cottonseed meal or 0.2 gram (0.2%) of ammonium sulfate. It is to be regretted that the several series could not all be run on exactly the same basis as the Hanford series. But the small amount of stock soils of the samples of the earlier series precluded the use of larger original samples, not to speak of the impossibility of repeating these series. The cultures were incubated for four weeks at 24°C–30°C. At the end of this period the cultures were dried in the oven at about 90°C and the nitrate content determined by the phenoldisulfonic acid method according to the modifications of Lipman and Sharp.⁵⁹

Nitrogen fixation. For this determination uniform quantities of soil were used throughout—50 grams, to which was added 1 gram of mannite. These cul-

⁵⁵ Hopkins, *Soil Fertility and Permanent Agriculture*, pp. 630–33; Hopkins and Pettit, *Soil Fertility Laboratory Manual* (Boston, Ginn, 1910), pp. 42–45.

⁵⁶ *Jour. Ind. Eng. Chem.*, vol. 5, pp. 993–1009.

⁵⁷ *Calif. Agr. Exp. Sta., Circ. 6* (1903), p. 21.

⁵⁸ Burgess, P. S., *Soil Bacteriology Laboratory Manual*, Easton, Pa., The Chemical Publishing Co., 1914.

⁵⁹ *Univ. Calif. Publ. Agr. Sci.*, vol. 1 (1912), pp. 21–37.

tures were incubated for four weeks at 24°C–30°C, at the end of which time bacterial action was stopped by drying in the oven for 24 hours. Subsequently, the samples were broken up in a mortar, and 10 grams weighed out for the determination of the total nitrogen.

POT CULTURES IN THE GREENHOUSE

The large samples of the surface foot of soil were stored in the greenhouse until used. The preparation of the samples was in most cases as follows: The sample was placed on a large table and screened through a quarter inch sieve. This treatment of screening was attempted with the Diablo clay adobe and the Altamont clay loam, but was abandoned as practically hopeless. The samples of these two types had been collected in the late summer, when the ground was very hard and dry, hence the clods defied any efforts to break them up. As an alternative the samples were as thoroughly mixed as possible and weighed out into the pots. Several waterings during a week, together with carefully breaking up the lumps by hand, rendered the soils finely divided enough to permit the planting of the seeds. The Hanford and San Joaquin types were readily screened.

All the soils were weighed out into nine inch flower pots. In most cases the pots had been previously paraffined. Care was taken to clean the pots thoroughly, as far as surface material was concerned; many of the pots were scrubbed with a brush and water. All previously used pots were examined to exclude the use of such as had formerly been used for soils containing high percentages of soluble salts, but such examination was not always successful in eliminating the undesirable pots, as was afterwards evident. In the Diablo, Altamont, and Hanford soils the quantity of soil used was five kilos per pot. In the San Joaquin soils six kilos were used.

Enough soil was collected to fill eighteen pots. This would allow for the arrangement of six sets of triplicates of every sample; and the planting of a different crop in each of the sets would allow for the growing simultaneously of six different crops on every soil. For example, there were placed together in the greenhouse and considered as a unit in the culture work the series of the Diablo clay adobe, including three pots of the sample taken from San Juan Capistrano, three from that taken near Los Angeles, three from that of the San Fernando valley, and lastly three from the sample taken in the Danville region. This group of pots was planted to oats, barley, bur clover, or any one other crop. The pots were kept together in the greenhouse, that the conditions for each one in the set would be as nearly uniform as possible, for even a slightly different location in the greenhouse was found to affect the crop appreciably. The other five sets of pots were similarly treated. No fertilizing materials were added to any of the soils. All were used in their normal condition. The aim was to compare the crop producing power of the representatives of a given type of soil from various localities.

Several crops were grown, as the desire was to get a series of plants that would grow well under greenhouse conditions, and act as indicators. It was known that barley was about the best crop to use, but supplementary plants were desired. Barley, wheat, oats, rye, millet, milo, cowpeas (black eye beans), soy beans, beans (small white), bur clover (*Medicago denticulata*), sweet clover (*Melilotus indica*), and oats and bur clover in combination were tried. Some were a marked success under greenhouse conditions, and others were practically total failures; the better crops were given by barley, soy beans, bur clover, and millet. Sweet clover gives excellent results. This wide range of varieties of plants was

necessary because of the fact that it was desired to grow two crops a year on the soils. The winter crops will not do well in summer, and vice versa, even though the summers in Berkeley are relatively cool, and though the greenhouse was whitewashed during the summer months.

The seed was obtained in most cases from the Division of Agronomy of the Department of Agriculture of the University of California. Such varieties as were not available from this source were obtained from the commercial seed houses in San Francisco.

Usually the seed was planted directly in the pots, using sufficient seed to be sure that enough would germinate and grow to give the desired number of plants per pot, usually six. After the plants were well established, and before there was any crowding in the pots, the plants were thinned. In some cases an insufficient number of plants germinated to give the desired number per pot. Difficulty was found in getting the soy beans and cowpeas to germinate, especially in the heavier soils. This was overcome by sprouting the seeds in an incubator and planting them when the radicle was half an inch long or more. An excellent stand was thus obtained.

No actual measurements of the height of the plants, or the length of leaves were made in the greenhouse work. But photographs were taken, and in these photographs the attempt was made to secure representative records of the entire series, without photographing the crop in every pot. The usual procedure in the Altamont and Diablo series was to photograph two pots out of each set of triplicates, an attempt being made to select average, representative pots. In the large Hanford series one representative pot of each set of triplicates in each crop series was photographed, and three representative sets of triplicates were also photographed. Thus some of the pots appear twice, and allow of comparisons.

If any doubt be entertained as to the relative weights of the crops in the pots photographed as compared with those not so recorded, the relative weights of the crops may be easily obtained by referring to the tables of dry weights. In practically every case the pot label can be read from the photograph. The method of labeling is exemplified as follows:

6 Soil sample no. 6 (Diablo clay adobe from Danville).

W Wheat, first crop.

2 Pot 2 of the triplicate set first planted to wheat.

CP Cowpeas, second crop.

During the growth of the crops, notes were taken as to the relative growths and the general conditions of the plants.

When the crop had ceased growing it was harvested, whether or not it was mature in the sense of having set and developed seed. The plants from a given pot were put in a paper bag, labeled, and placed in the drying oven for 24 hours. The plants were weighed when dry and cool. If any mature seed was produced it was weighed separately.

Between the first and second crops the soil was allowed to rest from two to three weeks or longer. Each pot was emptied and the soil passed through a quarter inch screen before replacing in the pot. This broke up the lumps and removed most of the roots. The roots were not saved. The weight of the roots would have been interesting, but their recovery, especially from the heavy soils, would have involved careful washing, and the loss of much of the soil. It was thought that some washing would be necessary, even in the Hanford series, in order that the resulting figures might be at all accurate.

APPENDIX B

SOIL SAMPLE LOCATIONS

FIELD NOTES ON THE SOIL SAMPLES COLLECTED

No. 1—Diablo Clay Adobe

Location: A little over a mile east of San Juan Capistrano, Orange County. On the lower slopes of the hills to the south of San Juan Creek. Sample station is on a little shoulder running northwest, between Mr. Echenique's house and the fence following the road to Prima Deshecka Canada. Approximately one-quarter mile from the above house.

Soil: 0-12 inches—Dark gray adobe; much cracked.

12-36 inches—Soil becomes gradually lighter in color, approaching a light bluish gray mottled with brown.

36 inches—The subsoil becomes a silty clay loam in the lower depths.

History: The field was pastured up to and including 1906. From 1907 to date the field has been annually planted to barley. Data from Mr. Echenique, the owner. Sample collected August 19, 1917.

Depths of horizons:

1-A	0-12 inches.	1-B	12-24 inches.	1-C	24-36 inches.
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No. 2—Diablo Clay Adobe

Location: One and three-quarter miles east of southeast of Eastlake Park, Los Angeles. Station is 0.7 mile by secondary road south of Pacific Electric railroad crossing, and 1.2 miles southeast of the Southern Pacific railroad crossing. Station is about 150 feet up the hill to the west of the road, in grain field, and 75 feet south of a 10 or 12 year old eucalyptus grove. The road, going south, emerges from the grove, and is then flanked by pepper trees.

Soil: 0-12 inches—Dark gray to almost black, but with a shade of brown rather than a bluish gray.

12-24 inches—Dark grayish brown clay adobe, becoming a little lighter with depth.

24-36 inches—Dark brown with soft, whitish fragments. Fragments probably the partially weathered parent rock, though no outcrops of the rock were seen in the vicinity. Previous to the collection of the sample, Mr. E. C. Eckman, who mapped the area as the Bureau of Soils representative, said in substance: "We have no good Diablo in the area; the body I am directing you to is as good as any, but it is pretty brown."

History: Property owned by Mr. Huntington. Farmed to grain the past 2 years; pasture previously. Data from the son of the tenant. Sample collected August 20, 1915.

Depths of horizons:

2-A	0-12 inches.	2-B	12-24 inches.	2-C	24-36 inches.
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No. 3—Altamont Clay Loam

Location: 1.4 miles southeast of Walnut, Los Angeles County, on the shoulder of a low hill, about 200 feet east of the wagon road running south through the hills. The station was selected so that the texture was about right, for in a very short distance there were variations from a heavy dark clay loam or clay adobe to the light clay loams.

Soil: 0-36 inches—A medium textured brown friable clay loam. The soil column throughout was more or less filled with small soft whitish fragments, portions of the parent rock.

36 inches—The weathered parent rock was encountered.

History: A. T. Currier, owner. The field is in pasture, and has not been cultivated for forty years, to the knowledge of the ranch foreman. The soil is probably virgin. Sample collected August 20, 1915.

Depths of horizons:

3-A 0-12 inches. 3-B 12-24 inches. 3-C 24-36 inches.

No. 4—Altamont Clay Loam

Location: On a hillside a few feet above the Cahuenga Pass (Burbank road), near Oak Crest, Los Angeles County. Just a few feet from the U. S. Bureau of Soils station for the type in the San Fernando area. (For map, see the map under sample no. 25.)

Soil: 0-14 inches—A dark brown clay loam.

14-36 inches—A yellowish brown loam, grading into the weathered, thin bedded shales at about 36 inches.

History: Roadside, above the big cut on the road, probably never tilled. The surface is not so steep but that it could be well tilled; some of the soil in the immediate vicinity is cultivated to grain. Sample collected August 21, 1915.

Depths of horizons:

4-A 0-12 inches. 4-B 12-24 inches. 4-C 24-36 inches.

No. 5—Diablo Clay Adobe

Location: About $\frac{1}{2}$ mile north of Calabasas, San Fernando Valley, Los Angeles County. The station is some distance up the hill to the west of the road running north from the Calabasas store. The sample was collected near the top of the hill, to the northeast of the oak tree.

Soil: A dark gray to black typical clay adobe. Distinctly heavy. Digging was very difficult, the soil coming up in large, very hard clods. The soil was of about the same color and texture down to the bedrock at 26 inches. The bedrock is a heavy claystone or shale.

History: John Grant, Calabasas P. O., owner. The land has been dry farmed to grain. Presumably there had been no additions of fertilizing materials to the soil. Sample collected August 21, 1915.

Depths of horizons:

5-A 0-14 inches. 5-B 14-26 inches. 26 inches. Parent rock.

No. 6—Diablo Clay Adobe

Location: In Contra Costa County, $\frac{1}{2}$ mile west of Tassajero; 6 miles east and a little south of Danville. Station about 150 feet up the hill to the south of the road, that is, about one-third of the way up the hill.

Soil: 0-34 inches—A black or dark gray clay adobe, moist at 10 inches.

34-72 inches—A dark grayish brown subsoil, becoming lighter below the third foot. No bedrock within the 6 foot section, nor was there any sign of any outcrop in the vicinity. The slope of the hill moderate, the exposure north. The sample was collected with the assistance of Mr. L. C. Holmes and Mr. E. C. Eckman, both of the U. S. Bureau of Soils. They pronounced the station typical.

History: Property owned by J. J. Johnson. The field has been farmed to grain for probably 60 years. Formerly the rotation was pasture one year, and grain one year; now the practice is grain two years, and pasture one year. Sample collected September 2, 1915.

Depths of horizons:

6-A 0-12 inches. 6-B 12-24 inches. 6-C 24-36 inches.

No. 7—Altamont Clay Loam

Location: On the Mission Pass road, a little less than 2 miles south and a little west of Sunol, Alameda County. About 100 feet above the road, between wooden electric power poles nos. 92/30 and 92/31.

Soil: 0-34 inches—A medium brown clay loam, considered typical by Mr. L. C. Holmes and Mr. E. C. Eckman of the U. S. Bureau of Soils. There were slight changes in texture.

34 inches—A stiff clay horizon.

Inspection of a deep cut on the roadside near the location of the sample station showed that at 6 feet and deeper there existed a heavy reddish clay. In the immediate locality the road sections showed that the parent rock was deeper than the 6 foot section. The slope of the land at the sample station was quite steep.

History: Tom Burns, Irvington, owner. Field has been in pasture for the past 3 years at least, and probably for a much longer time. Sample collected September 2, 1915.

Depths of horizons:

7-A 0-12 inches. 7-B 12-24 inches. 7-C 24-36 inches.

No. 10—San Joaquin Sandy Loam

Location: North Sacramento, Sacramento County; $\frac{1}{4}$ mile east of tile factory, across the road; opposite poles 57/32 and 57/33, 75 feet southeast from the State Highway.

Soil: 0-26 inches—A brownish red sandy loam, slightly hog wallowed, and very slightly rolling.

26-36 inches—A sandy clay loam.

36 inches—A hard hardpan.

History: Owner not known, the district now being subdivided, the property being a portion of the old "Hagan Grant." A near-by resident gave the following information: "The land has not been cultivated for the past 15 years or more. The land is said to have been farmed to grain at one time for a few years, but the 'soil is too light for wheat, it grows nothing but filaree.'" The principal use has been for cattle and sheep pasture. Sample collected March 28, 1916.

Depths of horizons:

10-A 0-12 inches. 10-B 12-24 inches. 10-C 24-36 inches.

No. 11—San Joaquin Sandy Loam

Location: Four miles west of Lincoln, Placer County, at the "Road Corners," in the southeast field, 10 feet east of the west fence and 60 feet south of the north fence.

Soil: A gently hog wallowed, sandy loam, with some deeper depressions, probably stream channels. Sample slightly gravelly.

0-12 inches—Brownish or reddish brown sandy loam.

12-17 inches—Sandy clay loam or clay, color the same.

17-23 inches—A stiff reddish brown clay.

23 inches—A hard hardpan.

History: Mr. Frank Dowd, owner. The land has been planted to wheat for the past 20 or 25 years; previous to that time it was used for pasture. Six to 10 or 12 bushels of wheat, and 8 to 20 bushels of barley is the production of this soil in the locality. The soil is usually fallowed on alternate years. Land held at from \$30 to \$50 per acre. Sample collected March 28, 1916.

Depths of horizons:

11-A 0-11 inches. 11-B 11-17 inches. 11-C 17-23 inches.

No. 12—San Joaquin Sandy Loam

Location: About 6 miles west of Wheatland, Sutter County. Near a road corner, in a little swale west of a knoll, 15 feet east of the westerly fence of field, and 150 feet south of the north line of the westerly road.

Soil: Texture slightly heavy, and barely enough sand for a sandy loam, but the best found for several miles. Color brownish red, the same throughout the entire depth.

0-18 inches—Light, fine textured, sandy loam.

18-31 inches—Heavy sandy clay loam, running into a stiff clay.

31 inches—Hardpan, sandy and somewhat soft. The ground was very moist at this time.

History: Very evidently pasture for sheep and cattle. No signs of having been cultivated for several years, at least. The cover is of a number of low annuals—*Orthocarpus*, *Trifolium*, *Centaurea*, and others. Sample collected March 29, 1916.

Depths of horizons:

12-A 0-12 inches. 12-B 12-18 inches. 12-C 18-31 inches.

No. 13—San Joaquin Sandy Loam

Location: Three and three-quarters miles east of Elk Grove, Sacramento County.

On the Sheldon road, about 30 feet northwest from the fence on the north side of the road. About 200 feet southwest from where a house formerly stood.

Soil: A reddish brown sandy loam, approaching a loam; becoming redder in color with increasing depth.

0-14 inches—Heavy sandy loam.

14-22 inches—Clay loam.

22-29 inches—Heavy clay loam.

29 inches—Compact hardpan.

History: Wackman Brothers, Elk Grove, owners. The land has not been plowed or farmed for at least 15 years. The land is held at about \$50 per acre. Sample collected March 30, 1916.

Depths of horizons:

13-A 0-12 inches. 13-B 12-22 inches. 13-C 22-29 inches.

No. 14—Hanford Fine Sandy Loam

Location: One mile southeast of the Sheldon road, $3\frac{1}{2}$ miles east of Elk Grove, Sacramento County. On the southwest side of the secondary road, in alfalfa field, about 25 feet from the fence. Station on a little rise.

Soil: 0-11 inches—A medium brown micaceous heavy fine sandy loam.

11-24 inches—A dark gray to black fine sandy loam, grading into the following.

24-36 inches—Brown fine sandy loam. Water table at 32 inches.

History: Mrs. A. C. Freeman, Elk Grove, owner. Land planted to alfalfa. Good growth. No irrigation. Willows as well as alders and river ash along the sloughs. Many scattering valley oaks. The land is subject to overflow from the Cosumnes River, as it lies low in the river bottom, and shallow stream channels and sloughs are frequent. Sample collected March 30, 1916.

Depths of horizons:

14-A 0-12 inches. 14-B 12-24 inches. 14-C 24-36 inches.

No. 15—Hanford Fine Sandy Loam

Location: North of Woodbridge, San Joaquin County, along the State Highway, less than $\frac{1}{4}$ mile south of the road running westerly from Acampo to the highway. Station in a vineyard, with almond trees along the roadside, 20 feet northeast of "change telephone pole," 200 feet north of pine tree at the gateway on the opposite side of the highway. (For map, see under sample 16.)

Soil: Texture a rather coarse fine sandy loam; it was hard to find a good fine sandy loam. Color when moist was a medium brown throughout the 3 foot section; the field color was a light grayish brown.

History: Mike Nolan estate, owner. The vineyard is of Tokay grapes, 10 to 12 years old. The land is held at \$300 to \$400 per acre. It is said to be a losing game to farm this land to grapes at this valuation. Sample collected March 30, 1916.

Depths of horizons:

15-A 0-12 inches. 15-B 12-24 inches. 15-C 24-36 inches.

No. 16—Hanford Fine Sandy Loam

Location: Along the road north of Woodbridge, San Joaquin County. In a young pear orchard about 65 feet west of the highway, and about 95 feet north of the north abutments of the bridge over Mokelumne River.

Soil: A medium brown fine sandy loam, similar throughout the soil column of three feet. This soil is of the recent, flood-plain phase of the type, though this station is not known to have been under water for a number of years, at least. There is only a comparatively narrow shelf of this phase between the older, higher phase, and the river.

History: A. Perrin, Woodbridge, owner. The land had always been in brush and pasture until it was cleared and planted to pears in 1911. Value about \$500 per acre. Sample collected March 30, 1916.

Depths of horizons:

16-A 0-12 inches. 16-B 12-24 inches. 16-C 24-36 inches.

No. 17—San Joaquin Sandy Loam

Location: A short distance south of the east and west road that runs east to Thalheim, San Joaquin County. The station was on a slight knoll 75 feet south of a canal, and the same distance east of the secondary road running north and south; not far from a vacant barn.

Soil: 0-12 inches—Reddish brown.

12-24 inches—Slightly redder.

24 inches—Hardpan.

The surface had the characteristic hog wallows, and the usual scant vegetation of grasses and herbs, "filaree" being abundant; yet all vegetation was more abundant than that in pastured fields.

History: Rev. Frank Hoffman, Acampo, owner. Apparently, the land has not been cultivated in recent years. Sample collected March 31, 1915.

Depths of horizons:

17-A 0-12 inches.

17-B 12-24 inches.

No. 18—San Joaquin Sandy Loam

Location: Two and one-half miles northwest of Madera, Madera County. Along State Highway, 75 to 100 feet southwest of the paved road, at telephone pole 92/29; across the highway from the driveway to the house.

Soil: 0-5 inches—A light reddish brown sandy loam. A noticeable plow pan at 5 inches.

5-24 inches—A light brownish red sandy loam, becoming heavier below.

24-30 inches—Quite compact heavy sandy loam.

30 inches and deeper—A *very compact* hardpan.

Topography very gently rolling, hog wallows well developed, though considerably degraded by cultivation. Barley grain not growing well in the lower spots.

History: Cropped for probably 20 years to grains; barley at present. Land used for pasture previous to grain farming. A good yield is 8 sacks, varying from that down to little or nothing. Miller and Lux, owners. Sample collected April 11, 1916.

Depths of horizons:

18-A 0-12 inches.

18-B 12-24 inches.

18-C 24-30 inches.

No. 19—Hanford Fine Sandy Loam

Location: Eight miles east of Waterford, Stanislaus County, near Robert's Ferry bridge. About 75 feet west of the road that runs south from the bridge onto the bluff. About 450 feet north of the driveway to the Sawyer place.

Twenty-five feet inside of the fence, in the alfalfa field.

Soil: Medium brown fine sandy loam; a good brown color when moist. Texture somewhat variable, some rounded gravels up to the size of a hen's egg. Topography undulating, and more or less terraced, due to the old stream channels.

History: G. H. Sawyer, Waterford, owner. Alfalfa planted in 1915, looks well. Land previously planted to barley and wheat, with a production about as follows: barley, 14 sacks is considered good; wheat with 12 sacks is good, with 6 sacks a low average. Value of the land as recently determined in court, in a case of flood damage by a canal break, is \$100 per acre. On an adjoining piece of land young walnut trees are doing very well. Sample collected April 11, 1916.

Depths of horizons:

19-A 0-12 inches.

19-B 12-24 inches.

19-C 24-36 inches.

No. 20—Hanford Fine Sandy Loam

Location: Near Hopeton, Merced County, 14 miles north of Merced. Less than $\frac{1}{4}$ mile north from the road corners, 15 feet east of the east fence of the road, and 150 feet south of irrigating ditch.

Soil: A good medium brown fine sandy loam. The color is especially good when the soil is moist. The topography is slightly uneven because of the old stream channels. Going north along the road from the cross roads the soil is quite gravelly at first, but the texture gradually becomes heavier, with less gravel. At the sample station the texture is a rather heavy fine sandy loam.

History: J. G. Ruddle, Snelling, owner. The field is planted to alfalfa, as are most of the Hanford soils in the locality. The land is not subject to overflow. Sample collected April 13, 1916.

Depths of horizons:

20-A	0-12 inches.	20-B	12-24 inches.	20-C	24-36 inches.
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No. 21—San Joaquin Sandy Loam

Location: Near Nairn Station, Merced County. About $\frac{1}{4}$ mile west of the railroad, 50 feet north of the private ranch road, and 120 feet east of the field gate across the road. About 4 miles northwest of Merced.

Soil: A good brownish red San Joaquin color. Texture a sandy loam, grading into a clay loam or clay at about 24 inches.

Depths of horizons:

24-27 inches—A heavy clay.

27 inches—Hardpan.

The same was taken from near the top of one of the hog wallow elevations. The topography is gently rolling.

History: F. W. Henderson, Merced, owner. At the present time the land is used as pasture. It has been plowed at some time in the past. The present growth of wild herbage (*Lepidium*, small grasses, *Cryptanthus*, etc.) is meager. Sample collected April 13, 1916.

Depths of horizons:

21-A	0-12 inches.	21-B	12-24 inches.	21-C	24-27 inches.
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No. 22—Hanford Fine Sandy Loam

Location: A short distance north of Basset, Los Angeles County, on the main road north from Basset station. The sample was collected in a walnut grove 100 feet east of the road and 250 feet south of the driveway to the ranch house.

Soil: A good medium brown when moist, and a light grayish brown when dry. Mr. L. C. Holmes, of the U. S. Bureau of Soils, described the soil at the time of collection as being "all a little browner, and with a little more color than a good Hanford." There was a very slight color change at about a foot, the soil below was grayer. Texture a good fine sandy loam, with practically no change in the 3 foot column. Topography smooth. The texture varies quite rapidly from place to place in the field. Some big washes of typical intermittent streams are found not far to the north and west.

History: C. N. Basset, of Basset and Nebeker, Santa Monica, owner. The land is planted to walnuts, and the trees are about 10 years old. They are doing well, some replants are found. The trees are irrigated. Sample collected May 22, 1916.

Depths of horizons:

22-A 0-12 inches. 22-B 12-24 inches. 22-C 24-36 inches.

No. 23—Hanford Fine Sandy Loam

Location: South and west of the town of Anaheim, Orange County. Within a radius of 20 feet of where the official Bureau of Soils sample was taken. Thirty feet east of side road, and 100 feet north of main east and west road.

Soil: Brown fine sandy loam, possibly a little more silty than no. 22, but not heavy enough for a heavy fine sandy loam. Dry field color a light, grayish brown. Topography smooth, no stream channels visible. Irrigation in furrows. Soil similar to about 62 inches, a little more grayish at 18 inches, the change being gradual. At 62 inches a gray clean sand, or fine sand, was found.

History: S. J. Lühring, R. F. D. no. 4, owner. The field was planted to Valencia oranges in 1913; previously to grapes and miscellaneous crops. Sample collected May 23, 1916.

Depths of horizons:

23-A 0-12 inches. 23-B 12-24 inches. 23-C 24-36 inches.

No. 24—Hanford Fine Sandy Loam

Location: Southeast of the center of Los Angeles, half way from Magnolia Avenue on Fruitland Road, to Salt Lake Railroad on the east. South side of the road about 60 feet from center, in edge of corn field. Just across road from east end of east cypress trees.

Soil: A medium brown fine sandy loam when moist; color in the field is a grayish brown. Micaceous. Topography level, no stream channels seen nearby. Color of body variable. Sample location in the browner phase. Toward south and east along the railroad and Areadia Avenue the color is much grayer, and even black when moist. Texture within the body is very variable, though always within the fine sandy loam group.

0-36 inches—Fine sandy loam, grayer below.

36-37 inches—Layer of grayish sand and fine sand.

37-72 inches—Fine sandy loam, heavier in streaks.

History: C. D. Templeman, R. F. D. no. 2, Box 178, Los Angeles, owner. Land has been in truck for 10 or 12 years. Only fertilizer, barnyard manure. Sample collected May 24, 1916.

Depths of horizons:

24-A 0-12 inches. 24-B 12-24 inches. 24-C 24-36 inches.

No. 25—Hanford Fine Sandy Loam

Location: Near Van Nuys, Los Angeles County; near official sample station. Seventy-five feet west of center of road, between fourth and fifth rows of apricot trees north from boundary.

Soil: A good medium brown fine sandy loam; the field color a grayish brown. The texture uniform throughout the 3 foot section, with a little gravel occasionally. Also the texture is variable to about the usual degree, in the field distribution. The color is slightly lighter at about 2 feet and below throughout the 6 feet, with a little variation in an increasing amount of coarser sands.

History: Chase, Riverside, owner (?). Planted to apricots, 2 years old. Interplanted to melons. Sample collected May 24, 1916.

Depths of horizons:

25-A	0-12 inches.	25-B	12-24 inches.	25-C	24-36 inches.
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No. 26—San Joaquin Sandy Loam

Location: On the high bluffs about 1¼ miles southeast of Del Mar station, San Diego County, close to the road that runs back along the main ridge. About 50 feet north of the road where it swings south to get around the head of the big arroyo from the north.

Soil: A brownish red sandy loam. Surface covered with a moderate growth of the low chapparal common to these exposed ridges. Soil heavily laden with iron concretions. Surface has the usual hog wallows characteristic of the San Joaquin series.

0-6 inches—Reddish brown sandy loam, many concretions. Dry.

6-13 inches—Clay (sandy), reddish in cracks, and bluish inside of lumps and where not weathered.

13-22 inches—Clay, mostly bluish gray.

22-38 inches—Boring very difficult, due to the heavy nature of the clayey moist material. Color bluish.

About 40 inches—Hardpan. Very compact.

History: Probably never farmed. Recently streets cleared, and an attempt made to sell lots for building. Value for agriculture—none without irrigation. Sample collected May 25, 1916.

Depths of horizons:

26-A	0-6 inches.	26-B	6-13 inches.	26-C	13-22 inches.
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A general view in the greenhouse, where all the pot culture work was carried on. The entire right hand bench was devoted to this study, also half again as much space not visible in the print.

DIABLO CLAY ADOBE—FIRST CROP

Pots of same and different representatives of a given soil type compared.

Fig. 1. Oats and bur clover. Left to right—Soil 1, pot 1; soil 2, pot 2; soil 5, pot 1; soil 6, pot 3.

DIABLO CLAY ADOBE—FIRST CROP

Pots of same and different representatives of a given soil type compared.

Fig. 2. Oats. Left to right—Soil 1, pot 1; soil 2, pot 3; soil 5, pot 2; soil 6, pot 2.

DIABLO CLAY ADOBE—FIRST CROP

Pots of same and different representatives of a given soil type compared.

Fig. 1. Bur clover. Left to right—Soil 1, pot 1; soil 1, pot 2; soil 1, pot 3.

DIABLO CLAY ADOBE FIRST CROP

Pots of same and different representatives of a given soil type compared.

Fig. 2. Bur clover. Left to right—Soil 2, pot 1; soil 2, pot 2; soil 2, pot 3.

DIABLO CLAY ADOBE—FIRST CROP

Pots of same and different representatives of a given soil type compared.

Fig. 1. Bur clover. Left to right Soil 5, pot 1; soil 5, pot 2; soil 5, pot 3.

DIABLO CLAY ADOBE—FIRST CROP

Pots of same and different representatives of a given soil type compared.

Fig. 2. Bur clover. Left to right—Soil 6, pot 1; soil 6, pot 2; soil 6, pot 3.

DIABLO CLAY ADOBE—FIRST CROP

Pots of same and different representatives of a given soil type compared.

Bur clover. Left to right—Soil 1, pot 1; soil 2, pot 2; soil 5, pot 2; soil 6, pot 1.

DIABLO CLAY ADOBE—SECOND CROP

Pots of same and different representatives of a given soil type compared.

Fig. 1. Dwarf milo (*a*) following oats. Left to right—Soil 1, pot 2; soil 1, pot 3; soil 2, pot 1; soil 2, pot 3; soil 5, pot 1; soil 5, pot 3; soil 6, pot 2; soil 6, pot 3.

DIABLO CLAY ADOBE—SECOND CROP

Pots of same and different representatives of a given soil type compared.

Fig. 2. Dwarf milo (*b*) following oats and bur clover. Left to right—Soil 1, pot 1; soil 1, pot 3; soil 2, pot 1; soil 2, pot 3; soil 5, pot 1; soil 5, pot 3; soil 6, pot 1; soil 6, pot 3.

DIABLO CLAY ADOBE—SECOND CROP

Pots of same and different representatives of a given soil type compared.

Fig. 1. Cowpeas, following wheat. Left to right—Soil 1, pot 1; soil 1, pot 2; soil 2, pot 1; soil 2, pot 2; soil 5, pot 1; soil 5, pot 2; soil 6, pot 2; soil 6, pot 3.

DIABLO CLAY ADOBE SECOND CROP

Pots of same and different representatives of a given soil type compared.

Fig. 2. Soy beans, following barley. Left to right—Soil 1, pot 1; soil 1, pot 2; soil 2, pot 1; soil 2, pot 3; soil 5, pot 1; soil 5, pot 2; soil 6, pot 1; soil 6, pot 2.

ALTAMONT CLAY LOAM—SECOND CROP

Pots of same and different representatives of a given soil type compared.

Cowpeas B, following barley. Left to right—Soil 3, pot 1; soil 3, pot —; soil 4, pot 1; soil 4, pot 3; soil 7, pot 1; soil 7, pot 3.

ALTAMONT CLAY LOAM—SECOND CROP

Pots of same and different representatives of a given soil type compared.

Fig. 1. Soy beans A, following oats. Left to right—Soil 3, pot 1; soil 3, pot 2; soil 4, pot 2; soil 4, pot 3; soil 7, pot 2; soil 7, pot 3.

ALTAMONT CLAY LOAM—SECOND CROP

Pots of same and different representatives of a given soil type compared.

Fig. 2. Soy beans B, following *Phaseolus*. Left to right—Soil 3, pot 2; soil 3, pot 3; soil 4, pot 1; soil 4, pot 2; soil 7, pot 1; soil 7, pot 2.

ALTAMONT CLAY LOAM—SECOND CROP

Pots of same and different representatives of a given soil type compared.

Fig. 1. Dwarf milo A, following wheat. Left to right—Soil 3, pot 2; soil 3, pot 3; soil 4, pot 1; soil 4, pot 3; soil 7, pot 1; soil 7, pot 3.

ALTAMONT CLAY LOAM—SECOND CROP

Pots of same and different representatives of a given soil type compared.

Fig. 2. Dwarf milo A, following bur clover. Left to right—Soil 3, pot 1; soil 3, pot 2; soil 4, pot 1; soil 4, pot 3; soil 7, pot 1; soil 7, pot 3.

HANFORD FINE SANDY LOAM—FIRST CROP

Pots of same and different representatives of a given soil type compared.

Fig. 1. Dwarf milo A. Left to right—Soil 14, pot 2; soil 15, pot 2; soil 16, pot 3; soil 19, pot 3; soil 20, pot 2; soil 22, pot 2; soil 23, pot 1; soil 24, pot 2; soil 25, pot 1.

HANFORD FINE SANDY LOAM—FIRST CROP

Pots of same and different representatives of a given soil type compared.

Fig. 2. Dwarf milo A. Left to right—Soil 15, pot 1; soil 15, pot 2; soil 15, pot 3; soil 20, pot 1; soil 20, pot 2; soil 20, pot 3; soil 23, pot 1; soil 23, pot 2; soil 23, pot 3.

HANFORD FINE SANDY LOAM—FIRST CROP

Pots of same and different representatives of a given soil type compared.

Fig. 1. Dwarf milo B. Left to right—Soil 14, pot 3; soil 15, pot 2; soil 16, pot 1; soil 19, pot 3; soil 20, pot 2; soil 22, pot 3; soil 23, pot 3; soil 24, pot 2; soil 25, pot 3.

HANFORD FINE SANDY LOAM—FIRST CROP

Pots of same and different representatives of a given soil type compared.

Fig. 2. Dwarf milo B. Left to right—Soil 14, pot 1; soil 14, pot 2; soil 14, pot 3; soil 22, pot 1; soil 22, pot 2; soil 22, pot 3; soil 23, pot 1; soil 23, pot 2; soil 23, pot 3.

HANFORD FINE SANDY LOAM—FIRST CROP

Pots of same and different representatives of a given soil type compared.

Fig. 1. Soy beans. Left to right—Soil 14, pot 1; soil 15, pot 1; soil 16, pot 2; soil 19, pot 2; soil 20, pot 3; soil 22, pot 1; soil 23, pot 3; soil 24, pot 1; soil 25, pot 3.

HANFORD FINE SANDY LOAM—FIRST CROP

Pots of same and different representatives of a given soil type compared.

Fig. 2. Soy beans. Left to right—Soil 14, pot 1; soil 14, pot 2; soil 14, pot 3; soil 16, pot 1; soil 16, pot 2; soil 16, pot 3; soil 23, pot 1; soil 23, pot 2; soil 23, pot 3.

HANFORD FINE SANDY LOAM—FIRST CROP

Pots of same and different representatives of a given soil type compared.

Fig. 1. Cowpeas B. Left to right—Soil 14, pot 1; soil 14, pot 2; soil 14, pot 3; soil 22, pot 1; soil 22, pot 2; soil 22, pot 3; soil 23, pot 1; soil 23, pot 2; soil 23, pot 3.

HANFORD FINE SANDY LOAM—FIRST CROP

Pots of same and different representatives of a given soil type compared.

Fig. 2. Cowpeas B. Left to right—Soil 14, pot 3; soil 15, pot 2; soil 16, pot 2; soil 19, pot 2; soil 20, pot 2; soil 22, pot 2; soil 23, pot 2; soil 24, pot 1; soil 25, pot 3.

HANFORD FINE SANDY LOAM—SECOND CROP

Pots of same and different representatives of a given soil type compared.

Fig. 1. Barley, following soy beans. Left to right—Soil 14, pot 2; soil 15, pot 1; soil 16, pot 3; soil 19, pot 3; soil 20, pot 1; soil 22, pot 2; soil 23, pot 3; soil 24, pot 3; soil 25, pot 1.

HANFORD FINE SANDY LOAM—SECOND CROP

Pots of same and different representatives of a given soil type compared.

Fig. 2. Barley, following soy beans. Left to right—Soil 14, pot 1; soil 14, pot 2; soil 14, pot 3; soil 19, pot 1; soil 19, pot 2; soil 19, pot 2; soil 19, pot 3; soil 23, pot 1; soil 23, pot 2; soil 23, pot 3.

HANFORD FINE SANDY LOAM—SECOND CROP

Pots of same and different representatives of a given soil type compared.

Wheat, following millet. Left to right—Soil 14, pot 1; soil 15, pot 1; soil 16, pot 1; soil 19, pot 3; soil 20, pot 1; soil 22, pot 1; soil 23, pot 1; soil 24, pot 1; soil 25, pot 3.

HANFORD FINE SANDY LOAM—SECOND CROP

Pots of same and different representatives of a given soil type compared.

Wheat, following millet. Left to right—Soil 16, pot 1; soil 16, pot 2; soil 16, pot 3; soil 22, pot 1; soil 22, pot 2; soil 22, pot 3; soil 24, pot 1; soil 24, pot 2; soil 24, pot 3.

HANFORD FINE SANDY LOAM—SECOND CROP

Pots of same and different representatives of a given soil type compared.

Fig. 1. Barley, following cowpeas. Left to right—Soil 14, pot 2; soil 15, pot 2; soil 16, pot 2; soil 19, pot 2; soil 20, pot 1; soil 22, pot 3; soil 23, pot 3; soil 24, pot 3; soil 25, pot 1.

HANFORD FINE SANDY LOAM—SECOND CROP

Pots of same and different representatives of a given soil type compared.

Fig. 2. Barley, following cowpeas. Left to right—Soil 19, pot 1; soil 19, pot 2; soil 19, pot 3; soil 20, pot 1; soil 20, pot 2; soil 20, pot 3; soil 23, pot 1; soil 23, pot 2; soil 23, pot 3.

HANFORD FINE SANDY LOAM—SECOND CROP

Pots of same and different representatives of a given soil type compared.

Fig. 1. Oats, following milo. Left to right—Soil 14, pot 3; soil 15, pot 2; soil 16, pot 2; soil 19, pot 1; soil 20, pot 2; soil 22, pot 1; soil 23, pot 3; soil 24, pot 1; soil 25, pot 1.

HANFORD FINE SANDY LOAM—SECOND CROP

Pots of same and different representatives of a given soil type compared.

Fig. 2. Oats, following milo. Left to right—Soil 14, pot 1; soil 14, pot 2; soil 14, pot 3; soil 15, pot 1; soil 15, pot 2; soil 15, pot 3; soil 24, pot 1; soil 24, pot 2; soil 24, pot 3.

HANFORD FINE SANDY LOAM—SECOND CROP

Pots of same and different representatives of a given soil type compared.

Melilotus indica, following cowpeas. Left to right—Soil 14, Pot 1; Soil 15, Pot 3; Soil 16, Pot 2; Soil 19, Pot 2; Soil 20, Pot 1.

HANFORD FINE SANDY LOAM—SECOND CROP

Pots of same and different representatives of a given soil type compared.

Melilotus indica, following cowpeas. Left to right—Soil 22, Pot 2; Soil 23, Pot 1; Soil 24, Pot 1; Soil 25, Pot 1.

HANFORD FINE SANDY LOAM—SECOND CROP

Pots of same and different representatives of a given soil type compared.

Melilotus indica, following cowpeas. Left to right—Soil 15, Pot 1; Soil 15, Pot 2; Soil 15, Pot 3; Soil 23, Pot 1.

HANFORD FINE SANDY LOAM—SECOND CROP

Pots of same and different representatives of a given soil type compared.

Melilotus indica, following cowpeas. Left to right—Soil 23, Pot 2; Soil 23, Pot 3; Soil 25, Pot 1; Soil 25, Pot 2; Soil 25, Pot 3.

HANFORD FINE SANDY LOAM—SECOND CROP

Pots of same and different representatives of a given soil type compared.

Bur clover, following milo. Left to right—Soil 14, Pot 1; Soil 15, Pot 1; Soil 16, Pot 2; Soil 19, Pot 1; Soil 20, Pot 1.

HANFORD FINE SANDY LOAM—SECOND CROP

Pots of same and different representatives of a given soil type compared.

Bur clover following milo. Left to right—Soil 22, Pot 1; Soil 23, Pot 1; Soil 24, Pot 1; Soil 25, Pot 1.

HANFORD FINE SANDY LOAM—SECOND CROP

Pots of same and different representatives of a given soil type compared.

Bar clover, following milo. Left to right—Soil 19, Pot 1; Soil 19, Pot 2; Soil 19, Pot 3; Soil 23, Pot 1; Soil 23, Pot 2.

HANFORD FINE SANDY LOAM—SECOND CROP

Pots of same and different representatives of a given soil type compared.

Bar clover, following milo. Left to right—Soil 23, Pot 3; Soil 25, Pot 1; Soil 23, Pot 2; Soil 23, Pot 3.

SAN JOAQUIN SANDY LOAM

Pots of same and different representatives of a given soil type compared.

Rye. Left to right—Soil 10, pot 2; soil 11, pot 1; soil 12, pot 2; soil 13, pot 3; soil 17, pot 3; soil 18, pot 1; soil 21, pot 1; soil 26, pot 1.

SAN JOAQUIN SANDY LOAM

Pots of same and different representatives of a given soil type compared.

Fig. 1. *Melilotus indica*. Left to right—Soil 10, pot 1; soil 11, pot 3; soil 12, pot 2; soil 13, pot 1; soil 17, pot 3; soil 18, pot 3; soil 21, pot 2; soil 26, pot 1.

SAN JOAQUIN SANDY LOAM

Pots of same and different representatives of a given soil type compared.

Fig. 2. *Melilotus indica*. Left to right—Soil 13, pot 1; soil 13, pot 2; soil 13, pot 3; soil 17, pot 1; soil 17, pot 2; soil 17, pot 3; soil 26, pot 1; soil 26, pot 2; soil 26, pot 3.

SAN JOAQUIN SANDY LOAM

Pots of same and different representatives of a given soil type compared.

Rye. Left to right—Soil 10, pot 1; soil 10, pot 2; soil 10, pot 3; soil 18, pot 1; soil 18, pot 2; soil 18, pot 3; soil 26, pot 1; soil 26, pot 2; soil 26, pot 3.

SAN JOAQUIN SANDY LOAM

Pots of same and different representatives of a given soil type compared.

Fig. 1. Barley. Left to right—Soil 10, pot 3; soil 11, pot 2; soil 12, pot 3; soil 13, pot 1; soil 17, pot 3; soil 18, pot 2; soil 21, pot 3; soil 26, pot 1.

SAN JOAQUIN SANDY LOAM

Pots of same and different representatives of a given soil type compared.

Fig. 2. Barley. Left to right—Soil 10, pot 1; soil 10, pot 2; soil 10, pot 3; soil 18, pot 1; soil 18, pot 2; soil 18, pot 3; soil 26, pot 1; soil 26, pot 2; soil 26, pot 3.

SAN JOAQUIN SANDY LOAM

Pots of same and different representatives of a given soil type compared.

Fig. 1. Oats. Left to right—Soil 10, pot 1; soil 11, pot 1; soil 12, pot 2; soil 13, pot 1; soil 17, pot 2; soil 18, pot 3; soil 21, pot 1; soil 26, pot 3.

SAN JOAQUIN SANDY LOAM

Pots of same and different representatives of a given soil type compared.

Fig. 2. Oats. Left to right—Soil 11, pot 1; soil 11, pot 2; soil 11, pot 3; soil 17, pot 1; soil 17, pot 2; soil 17, pot 3; soil 21, pot 1; soil 21, pot 2; soil 21, pot 3.

SAN JOAQUIN SANDY LOAM

Pots of same and different representatives of a given soil type compared.

Fig. 1. Wheat. Left to right—Soil 10, pot 1; soil 11, pot 3; soil 12, pot 1; soil 13, pot 1; soil 17, pot 1; soil 18, pot 2; soil 21, pot 1; soil 26, pot 3.

SAN JOAQUIN SANDY LOAM

Pots of same and different representatives of a given soil type compared.

Fig. 2. Wheat. Left to right—Soil 10, pot 1; soil 10, pot 2; soil 10, pot 3; soil 13, pot 1; soil 13, pot 2; soil 13, pot 3; soil 17, pot 1; soil 17, pot 2; soil 17, pot 3.

SAN JOAQUIN SANDY LOAM

Pots of same and different representatives of a given soil type compared.

Fig. 1. Bur clover. Left to right—Soil 10, pot 2; soil 11, pot 2; soil 12, pot 3; soil 13, pot 1; soil 17, pot 3; soil 18, pot 2; soil 21, pot 1; soil 26, pot 3.

SAN JOAQUIN SANDY LOAM

Pots of same and different representatives of a given soil type compared.

Fig. 2. Bur clover. Left to right—Soil 10, pot 1; soil 10, pot 2; soil 10, pot 3; soil 18, pot 1; soil 18, pot 2; soil 18, pot 3; soil 26, pot 1; soil 26, pot 2; soil 26, pot 3.

UNIVERSITY OF CALIFORNIA PUBLICATIONS—(Continued)

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