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Development and Evaluation of Laboratory Methods for Determining the Nitrogen Supplying Power of the Irrigated Soils of Northern Utah

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DEVELOPMENT AND EVALUATION OF LABORATORY METHODS FOR DETERMINING THE NITROGEN SUPPLYING POWER OF THE IRRIGATED SOILS OF NORTHERN UTAH

by

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INTRODUCTION

Nitrogen is the most widely needed and the most widely used of the fertilizer elements. Yet, in spite of the voluminous research work of evaluating the nitrogen status of soils, laboratory tests for the purpose of predicting need of nitrogen fertilizer are not very widely used. In general, laboratory tests for nitrogen supplying power have not given satisfactory results. Methods currently employed by a few laboratories can be classified either as biological or chemical. In the former method, the soil is incubated under optimum conditions and the amount of nitrate released over a given period of time is measured and used as an index to the nitrogen supplying power of the soil. In the latter method a portion of the total nitrogen is released by chemical means and measured. An attempt is made using chemical methods to release the same amount or a constant portion of the amount of nitrogen that normally would be furnished to a growing plant by the soil during one season.

An obvious disadvantage of the biological or nitrification method as a basis for predicting fertilizer needs is the relatively long time required to complete a test. On the other hand, some investigators (5) have found that nitrification test values have correlated better with nitrogen supplying power of soils as measured by growing plants in the greenhouse than have chemical test values.

The need for a laboratory method of evaluating the nitrogen status of the irrigated soils of Utah has been recognized for a number of years. This need becomes more keenly felt as the use of the soil test for available phosphorus increases. Until now, past cropping and past

fertilizer history and future crop needs have been the main criteria on which to base nitrogen fertilizer recommendations. While these criteria are certainly of value, they are, nevertheless, incomplete; some indication of the present status of the soil nitrogen is needed.

This study was undertaken to develop a new method and to better evaluate present methods of measuring the nitrogen supplying power of the irrigated soils of northern Utah. The alkaline permanganate hydrolyzation as developed by Kresge and Merkle (12), a modification of the alkaline permanganate hydrolyzation, and the incubation method as developed in Iowa (14) along with the total nitrogen and organic carbon were studied in relation to greenhouse results with 111 soil samples collected from the irrigated farm areas of northern Utah. The effects of texture and past crop on the status of the soil nitrogen were also studied.

REVIEW OF LITERATURE

Incubation methods

More work has been devoted to incubation methods of measuring the nitrogen supplying power of the soil than any other method. With the realization that nitrogen becomes available as a result of biological activities, it is natural to try to measure the nitrogen supplying power of the soil by measuring the biological activity of the soil. This is usually done in one of two ways: a direct measurement of the nitrates produced during a period of incubation, or by a measurement of CO_2 evolved during an incubation period. The general approach to incubation methods has been to hold the soil at optimum incubation conditions for a period of time and then measure the nitrate produced or CO_2 evolved, and the results are used as an index to the nitrogen supplying potential of the soils.

Some of the workers (6, 8, 12) have used relatively long incubation periods in their attempts to measure the nitrogen supplying power of the soil. While they found a fairly good correlation between the nitrifiable nitrogen and the amount of nitrogen released by the soil (this is usually measured by the nitrogen uptake of a crop), the values of such results are somewhat limited. Because of the long period of time involved in this type of determination, it appears to have little value as a means for predicting nitrogen fertilizer needs. However, this method is an important means of evaluating cropping and rotation practices, fertility practices, the nitrogen characteristics of a specific soil type, and as a means of studying the processes of nitrification. In the work of Kresge and Merkle (12) the nitrate produced during a 12-week

incubation period was used as a standard for the evaluation of some chemical extraction methods.

In an effort to have an incubation test that could be used as a basis for making fertilizer recommendation, shorter incubation methods were developed. Workers at Iowa (5, 14) developed an incubation method using a two-week incubation period. This method is relatively inexpensive and can be adapted to routine analysis. The value of this test in predicting fertilizer needs of corn was studied by Hanway and Dumenil (7). They found that there was a close relationship between the test values and the response of corn to added nitrogen fertilizer in a field experiment. In an attempt to control some of the variables that are present in field experiments, Munson and Stanford (13) used a greenhouse experiment. German millet was used as an indicator plant, and the response of the millet to added nitrogen fertilizer was correlated with the two-week incubation test results. Where the nitrogen uptake by the millet was used as a measure of yield, the correlation between the test values and the yield values was very good ($r = .905$). Where the dry weights of the plants were used as a measure of yields the correlation was not nearly as good.[1] This incubation method (14) is presently being used in Iowa as a basis for making nitrogen fertilizer recommendations.

The indirect incubation methods are of two general types (9); one is a measurement of CO_2 evolved during an incubation of a soil sample, and the other involves an addition of a carbohydrate in excess--usually cellulose--so that the soil nitrogen is the limiting factor in the evolution of CO_2.

While the indirect incubation methods are not popular as a means of

1. It was felt that the reason for poor correlation was a deficiency of potassium which limited plant growth in some of the soils.

determining the nitrogen supplying power of the soil, they do have some advantages over the direct incubation methods. There are no extractions to be made, and in the case of the cellulose decomposing type there are no accumulations of nitrates, which tend to interfere with the microbiological activity. The work of White et al. (17) showed a fairly good correlation between indirect incubation determination and crop yields.

While the incubation method--particularly the Iowa method--may at present be the best means of measuring the nitrogen supplying power of the soil, it still leaves a lot to be desired. The time involved is often a disadvantage in making fertilizer recommendations. Also, the work of Harpstead and Brage (10) indicated that the influence of storage time on soil samples may be a disadvantage to incubation methods. They found that nitrate production was closely related to storage time, and that there was no significant correlation between the production of nitrate during a two-week incubation period and the response of oats to fertilization on samples that had been stored less than 18 weeks. After 18 weeks of storage, however, the correlation was found to be significant. Harmser and VanSchreven (9) maintain that the interpretation of incubation results are reliable only when restricted to one type of soil, one climatic zone, and one farming system, and for each set of conditions the interpretation of results must be developed separately.

Chemical extraction methods

To overcome some of the disadvantages of the incubation methods, there has been considerable interest in the development of a chemical extraction method for determining the nitrogen supplying power of the soil. Many types of chemical extractions have been tried, everything from the water extraction of the inorganic fraction of soil nitrogen to the determination of total nitrogen in soil.

Probably the earliest attempt to measure the nitrogen status of the soil was the determination of the inorganic fractions, particularly the nitrate. However, because of the dynamic condition of these inorganic fractions, there is little correlation between the amounts of nitrate and/or ammonium found in the soil at any one time and the amount that will be available to the plants during the growing season. Only by a careful evaluation of the environmental conditions--particularly the movement of moisture, plant density, and stage of plant growth--can these determinations be of any value.

There have been many attempts to evaluate nitrogen supplying power of the soil by measurement of its total nitrogen content (1, 2, 6, 12, 13, 17). White et al. (17) found the correlation between total nitrogen values and crop response to nitrogen fertilizer to be as close as the correlation between incubation values and crop response to nitrogen fertilizer. Kresge and Merkle (12) considered the correlation between total nitrogen values and the nitrate released during a 12-month period insignificant. The work of Munson and Stanford (14) showed an r-value of .814 for the correlation between total nitrogen and nitrogen uptake by millet in a greenhouse study as compared to an r-value of .905 for the correlation with the incubation method (7) and nitrogen uptake. The work of Allison and Sterling (1) indicated that for a given soil type under similar climatic conditions the total nitrogen is a rough index of the nitrogen supplying power of the soil.

Some attention has been given to the organic matter content of the soil as an index to its nitrogen supplying power. The results are similar to those found for total nitrogen. The results of White et al. (17) indicated that the organic matter content of the soil was just as good an indication of its nitrogen supplying power as is total nitrogen

content. Allison and Sterling (1) concluded that quantity of organic matter under normal conditions was more important than source or quality.

The general approach in recent years has been to develop a chemical extraction that will extract that portion, or a consistent amount of that portion, of soil nitrogen that will become available during the growing season. Truog (15) has developed a method using an alkaline permanganate hydrolyzation. Munson and Stanford (14) ran a correlation of Truog's alkaline permanganate method with nitrogen uptake by millet and found that the r-value was somewhat lower than similar comparisons of both incubation and total nitrogen determinations with the nitrogen uptake by millet. Kresge and Merkle (12) modified Truog's alkaline permanganate method. They compared the amount of nitrogen released by the modification and the amount released during a 12-week incubation period, found r-values as high as .8924, and concluded that the amount released by the modification was a fair indication of the nitrogen supplying power of the soil.

Although the incubation methods are still considered by some investigators more relieable than the chemical extraction methods, a more thorough evaluation of the latter seems worthwhile. Chemical extractions are advantageous in that they are better adapted to routine analysis, and results can be obtained in a relatively short period of time. Another feature of chemical extraction methods is that they may not be affected as much by sampling and storage procedures as are the incubation methods, but this has not yet been clearly demonstrated.

The problem of evaluating a nitrogen test is a difficult one. Greenhouse experiments such as the one used by Munson and Stanford (6), the amount of nitrates released during long-term incubation, and crop

yields from field trials are all being used as criteria for the evaluation of soil nitrogen tests. However, only after several years of correlation with field trials can a soil nitrogen test be adequately evaluated. It is essential that the unpromising tests be eliminated before they are subjected to long-term trials in the field.

Present methods for evaluating the nitrogen supplying power of any given soil are not satisfactory. It is realized that because of the nature of the soil nitrogen and the complex mechanisms by which it is released, the development of a reliable procedure for measuring its status constitutes a real problem. It should also be recognized that predictions concerning the amount of nitrogen that will become available in a given soil will probably never reach the degree of accuracy with which availabilities of phosphorus and potassium can be predicted. As suggested by Kresge and Merkle (12), "...those conditions which control nitrification and which control nitrate utilization by the crop and disappearance from the soil are of greater importance than is the quality of existing soil nitrogen per se." Nevertheless, a method for measuring the nitrogen supplying power of the soil is needed that would enable economical fertilizer recommendations to be made.

METHODS OF PROCEDURE

Collection of samples

One hundred and eleven soil samples were collected from irrigated farms in the northern part of the state of Utah (table 5, appendix). Ninety-one of the samples were collected in April 1957, and the remaining 20 were collected during October 1957. The samples were taken from the plow depth by shovel and represented three textural groups: fine, medium, and coarse. Each textural grouping also contained soils whose previous crop was alfalfa, beets, corn, or grain. Care was taken during the sampling to avoid fields where unusual conditions such as a high salt content or high alkalinity existed. Also, during the spring sampling, fields that had recently been fertilized with nitrogen were avoided. The county agents assisted in contacting cooperating farmers. One hundred-pound samples of soil were obtained by taking composite samples from a representative area in the fields sampled. Samples were air-dried and screened to pass through a one-fourth-inch sieve, and at the same time a three- to four-pound subsample was taken and further screened to pass through a two mm. sieve. These subsamples were used for all the laboratory determinations. The remaining soil was stored in labeled paper bags for greenhouse study.

Greenhouse study

The greenhouse experiment was begun during the latter part of November 1957. There were three treatments per sample and four replications of each treatment, making a total of 1332 pots. The soils were placed at random on five benches in the greenhouse. Twenty-four-ounce waxed Dixie cups were used for the pots. Drainage was provided by a

small hole and a half inch of pea gravel in the bottom of each cup. The pots were set in shallow containers—five-ounce Dixie cups--so as to contain any of the leachate that came through. The pots were filled to about one-half inch from the top--approximately two pounds of soil--and hulless barley (B855-14) was planted at the rate of 20 seeds per pot. After emergence the plants were thinned to ten seedlings per pot. A thin layer of vermiculite was added to the soil surface to help prevent or reduce crusting and also to help keep the soil from being splashed about when water was added.

Fertilizer was applied to the pots three weeks after planting in aqueous solutions of NH_4NO_3 and/or KH_2PO_4. The treatments consisted of three levels of nitrogen: 0, 60, and 120 pounds per acre. Phosphorus and potassium were added to each pot at the rates of 100 pound P_2O_5 per acre and 156 pound K_2O per acre. Treatment designations of N_0, N_1, and N_2 are used to designate the 0, 60, and 120 pounds per acre levels of nitrogen, respectively.

Forty-four days after planting the plants were harvested and the fresh-plant weight recorded. Plant growth at this time was close to the boot stage. Only those portions of the plants growing above the soil surface were harvested. The plant tissue was dried in a forced-air dryer at 65° C, and the dry weights recorded. Prior to analyzing, the plant tissue was ground in a Wiley mill. The percent nitrogen content of the plant material[1] was determined by the Kjeldahl method and the nitrogen yield calculated.

Laboratory procedures

In the laboratory several determinations were made on the soil

1. It was necessary to composite treatment replications to provide adequate plant material for total nitrogen determinations.

samples. These determinations included organic carbon, the Kresge-Merkle hydrolyzation (12), an acid-alkaline hydrolyzation, nitrifiable nitrogen (14), and total nitrogen on both the soil and plant samples.

Organic carbon determination. Organic carbon was determined by the Walkley-Black method (16). Ten ml. of XN $K_2Cr_2O_7$ plus 20 ml. concentrated H_2SO_4 are added to one g. of soil (or less) depending on the amount of organic matter in the soil. After the beakers had cooled ten minutes, about 150 ml. of water plus 25 ml. of X/2N $Fe(NH_4)_2(SO_4)_2$ were added. The solution was then back titrated over a titration light with $KMnO_4$. The percent organic carbon was calculated, assuming that 74 percent of the carbon is oxidized.

Kresge-Merkle hydrolyzation. The Kresge-Merkle hydrolyzation method (12) consisted of distilling the ammonia produced by treating 20 g. of soil with eight ml. of $KMnO_4$ solution (50 g. per liter), eight ml. of NaOH (300 g. per liter), and 284 ml. of distilled water into three percent boric acid solution. The ammonium was determined by titrating with .0715 N H_2SO_4. Excess bumping and foaming were prevented by adding granular zinc and a few drops of mineral oil. Approximately 100 ml. were distilled over in 30 minutes. The distillation was carried out in a macro-Kjeldahl apparatus.

Acid-alkaline hydrolyzation. The acid-alkaline hydrolyzation method used was similar to the Kresge-Merkle hydrolyzation except that the distillation was preceded by a digestion with 2N HCl.[2] Ten grams of soil was digested with 2N HCl in a 800 ml. Kjeldahl flask for five minutes (the mixture was allowed to boil for five minutes). Following digestion,

2. Earlier work of Kadhim (11) suggests that it might be desirable to include a greater amount of the soil nitrogen in the soil test. This was accomplished by the acid digestion.

200 ml. of distilled water, one g. $KMnO_4$, and 20 ml. of 50 percent NaOH were added to the flasks. Granular zinc and mineral oil were used to restrict the bumping and foaming. By using various distillation times, it was found that a distillation time of about 30 minutes or until a volume of 100 ml. of distillate was collected was an adequate distillation time. Any variation in the digestion time between four and ten minutes had very little effect on the amount of ammonia released. Also, varying the amount of HCl between 100 and 200 ml. had no noticeable effect.

It was found during the development of the acid-alkaline hydrolyzation method that the amounts of $KMnO_4$ used were quite critical (figure 1). While the amounts of ammonia released using one g. of $KMnO_4$ per ten g. of soil varied with the different soils, it was also found that there was a linear relationship between the amount of $KMnO_4$ used and the amount of ammonia released on the same soil. This linear relationship continued as such until a leveling off point was reached, usually between two and three g. of $KMnO_4$ per ten g. of soil, depending primarily on the total amount of nitrogen in the soil.

Nitrifiable nitrogen determination. Nitrifiable nitrogen was determined by a two-week incubation at 35° C. The method followed was essentially that developed at Iowa (14). Ten grams of soil was mixed with an equal volume of plaster finish exfoliated vermiculite in a filter tube[3] using a glass wool filter.[4] A pad of glass wool was also

3. The filter tube was made by drilling a small hole in the bottom of a glass vial 29 mm. in diameter and 98 mm. long.
4. The glass wool filters were made by rolling out the glass wool to the desired thickness (about two mm.) and then wetting and cutting it to the desired size with a cork bore. The filters were used wet, thus enabling the soil and vermiculite to be mixed in the filter tubes. The glass wool contained fibers measuring between .0002 and .0003 inches in diameter.

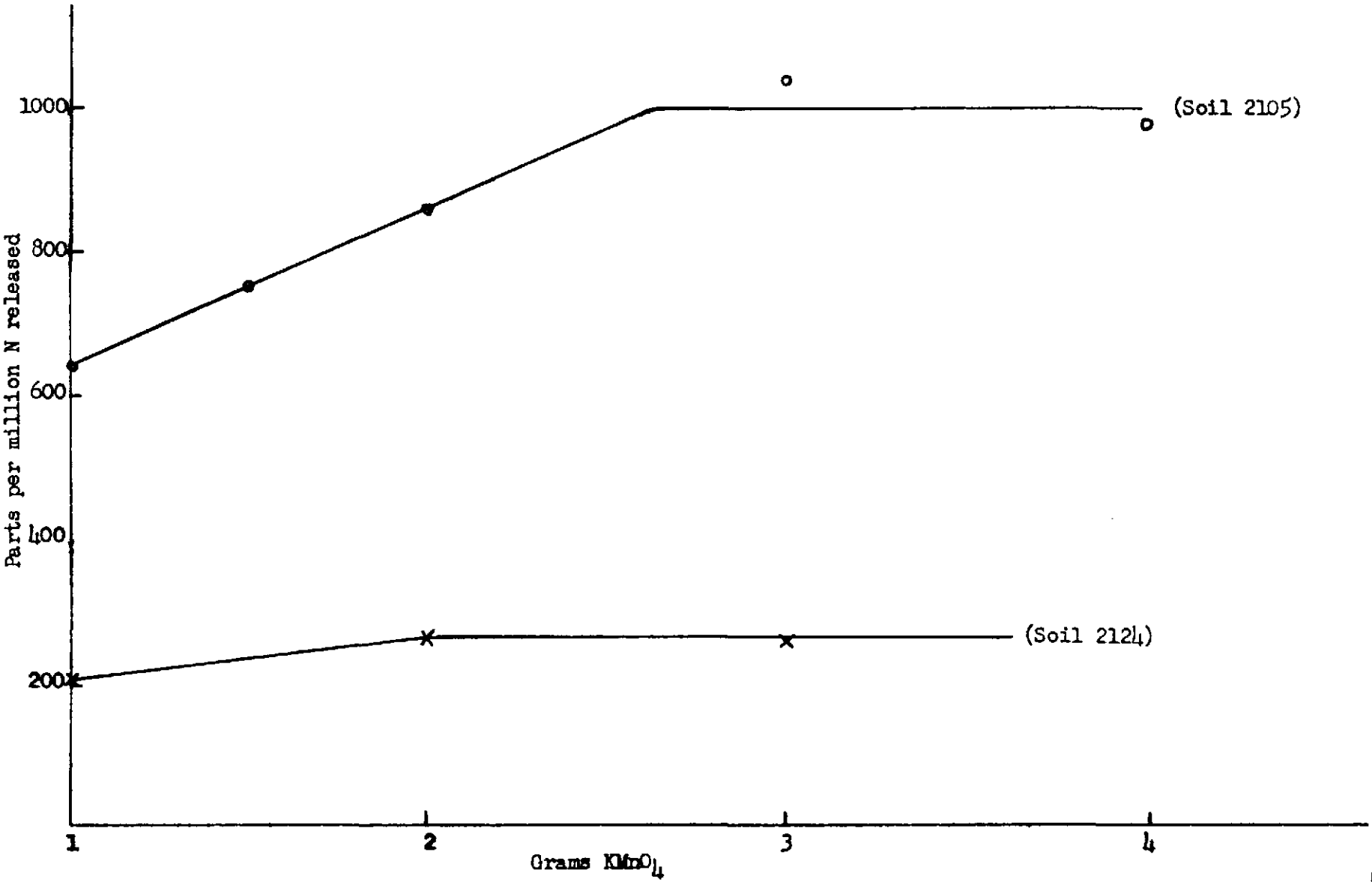

Figure 1. Nitrogen release curves for two soils using increasing amounts of $KMnO_4$ for the acid-alkaline hydrolyzation method

placed on top of the soil in the filter tube. The glass wool served the dual purpose of protecting the sample from splashing when water was poured on it, and it also helped reduce the evaporation of the moisture from the soil. The samples were leached with a 20-ml. portion of .004 percent Krilium (Monsanto 12) and two 20-ml. portions of distilled water. A vacuum of 100 cm. H_2O was used to facilitate the leaching and also to remove the excess water prior to incubation. Stanford and Harvey (14) found that a moisture tension of 100 cm. H_2O was apparently the optimum moisture level for nitrification. The short period of time the vacuum was applied was insufficient to assure that a moisture tension of 100 cm. H_2O had been reached, but it was felt that a tension of 100 cm. H_2O was approximated in the soil samples and that the reduced vacuum also reduced the compaction of the soil in the filter tube--a condition that nearly always occurred when a high vacuum was used. After incubation the samples were again leached with three 20-ml. portions of distilled water, and the nitrate nitrogen was determined by the phenol-disulfonic acid method. The temperature in the incubator was controlled at 35° C ± 5°. A small fan was placed in the bottom of the incubator to assure a proper movement of air. The fan was connected to the heating elements and ran only during the intervals that the elements were heating. The humidity in the incubator was maintained between 95 and 96 percent with water in shallow containers.

Total nitrogen determination. Total nitrogen on both the soil and plant samples was determined by the macro-Kjeldahl method. Ten g. of soil (one g. plant tissue) was placed in an 800 ml. Kjeldahl flask. To the soil was added approximately 10 g. Na_2SO_4 plus 25 ml. concentrated H_2SO_4 containing one part in 2000 by volume of $SeOCl_2$. The mixture was

then digested until the solution began to clear, usually 30 to 40 minutes. For plant samples the clearing was usually complete in 30 minutes. The flasks were then allowed to cool (approximately 10 minutes) after which a 250 ml. beaker of distilled water and a few boiling chips were added to each flask. The contents of the flasks were then made basic by the addition of 100 ml. of approximately 50 percent NaOH solution. A pinch of granular zinc was added to each flask and they were immediately connected to the condenser. The ammonia was distilled over into a three percent boric acid solution and determined quantitatively by back titrating with .0715N H_2SO_4. The distillation was continued until about 250 ml. distillate had been collected.

Statistical analysis

An analysis of variance (table 4) was run on the greenhouse data. Correlation coefficients were determined for the correlation between the various soil tests and nitrogen uptake on the N_0 pots (table 1). An attempt was made to correlate the response of barley to added nitrogen fertilizer, as measured by percent increase of the fertilized pots over the unfertilized, with the various soil tests. However, a preliminary investigation with a scatter diagram indicated that there was little or no relationship between the two, and therefore the calculation of the correlation coefficients was omitted. Correlation coefficients between the various soil tests were determined (table 2). Also, correlation coefficients for the relationship between fresh and dry plant tissue weights and nitrogen uptake by the plants were determined.

To compare the various soil tests as to their reproducibility or precision (table 3), part of the soil samples (about 20) were run in triplicate for each soil test except the incubation test. With the incubation test all samples were run at least twice and about half were

run in triplicate, and all of the results were used to calculate the precision of the incubation test.

necessity for mixing an inert filler such as sand to improve the physical condition of the soil. Munson and Stanford (13) mixed equal amounts of sand with the soil for their greenhouse work. Furthermore, it appeared that use of 2½-ounce Dixie cups as pots limited the number of plants that could be grown to such an extent that any variations in plant population or plant characteristics greatly exaggerated the yield values. Also, the large number of pots limited the choice of experimental design and hindered the uniform handling of all the pots, and thus the experimental set-up became unwieldy under greenhouse conditions.

The correlation between the various soil test values (table 2) indicates that little difference in the chemical soil tests was found.

Table 2. Correlation between soil tests' values

Soil test	Correlation coefficients (r)
Organic carbon and total nitrogen	.974**
Acid-alkaline hydrolyzation and total nitrogen	.855**
Kresge-Merkle and total nitrogen	.838**
Incubation and total nitrogen	.234*
Kresge-Merkle hydrolyzation and A-AH	.790**
Kresge-Merkle and incubation	.239**

** Significant at the 1 percent level
* Significant at the 5 percent level

The data also indicate that the two hydrolyzation methods used in this experiment are of little, if any, improvement over total nitrogen or organic carbon determinations for measuring the nitrogen supplying power of the soil.

Tables 1 and 2 show that the incubation test values gave the poorest correlation with the yield data and also with the total nitrogen in the soil. The poor correlation with the yield data can be partly

attributed to the two factors mentioned previously, i.e., the inability of the various soil nitrogen tests to measure that fraction of nitrogen that will become available to growing plants, and the inability of the nitrogen uptake by the barley plants to measure adequately the nitrogen supplying power of the soil. It is apparent, however, that there are more than just these two factors involved. The poor correlation of the incubation test values with the total nitrogen test values and also the poor precision of the incubation test (table 3) indicate that there was a malfunction of the method itself. In an earlier study, Kadhim (11) experienced difficulty in getting good precision with the Iowa incubation method. It was noted during the initial leaching of the samples that the leaching time for duplicate samples run side by side varied as much as 20 to 30 minutes. It appears that the leaching of the sample as prescribed by the incubation method constitutes a major problem for certain types of Western soils. Perhaps an incubation method that required no leaching would prove more successful on Western soils.

Table 3. The precision of the soil tests

Soil test	Average percent deviation of determinations on the same samples*
Total nitrogen	1.1
Organic carbon	2.6
Acid-alkaline hydrolyzation	6.9
Kresge-Merkle hydrolyzation	7.2
Incubation	15.9

* Average percent deviation = $\frac{\text{Avg. deviation from the mean}}{\text{mean}} \times 100$

The correlation coefficient for the correlation of the fresh plant tissue weights and the dry plant tissue weights with nitrogen yield are .9509 and .8956, respectively. This indicates that the fresh weights

would have been a satisfactory index to nitrogen uptake. It was somewhat surprising to find that the fresh tissue weights correlated more closely with the nitrogen uptake than did the dry tissue weights, especially since the dry weights were used to calculate nitrogen uptake.

Some interesting information concerning the effect of previous crop and texture on the nitrogen status of the soil was also obtained from this study. Using the average yield of nitrogen, the N-values for soils whose previous crop was beets, corn, alfalfa or grain were determined (figure 2). The N-values for the three textural groups--fine, medium, and coarse--were also determined (figure 3). These N-values were obtained by plotting the average yields on the vertical axis and the nitrogen application on the horizontal axis. The regression equations for the lines through these points were calculated and the regression line extrapolated to the X axis intercept. The point of intersection is considered the N-value or the amount of nitrogen furnished by the soil. The validity of this assumption has not been definitely established, but it has been used by other workers (12). Dean (3) found good correlation between the A-values for phosphorus as determined by this method and as determined by use of radio active phosphorus.

The results show the biggest difference between the N-values for the soils whose previous crop was grain and the other three crops. While there is little difference between the other three crops--beets, alfalfa, and corn--it was somewhat surprising to find soil following a corn crop with the highest N-value. A possible explanation for this is that these samples may have been taken from farms that used a better than average fertilizer program. Large applications of nitrogen to a corn crop may have resulted in a carry over of some nitrogen. Also, during the collections of samples the corn stubble appeared to be more

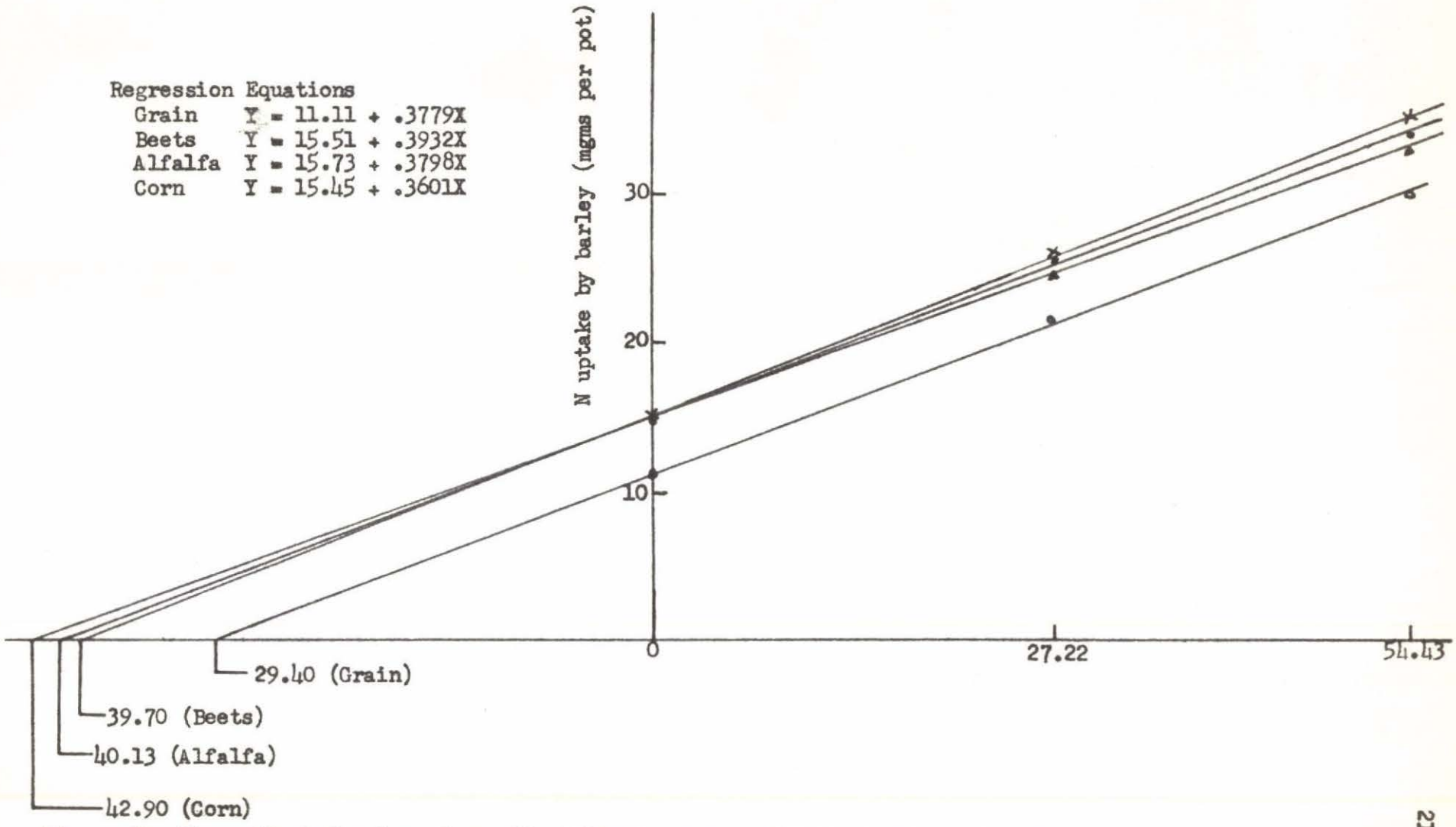

Figure 2. Theoretical N-values for soils following corn, alfalfa, beets, and grain

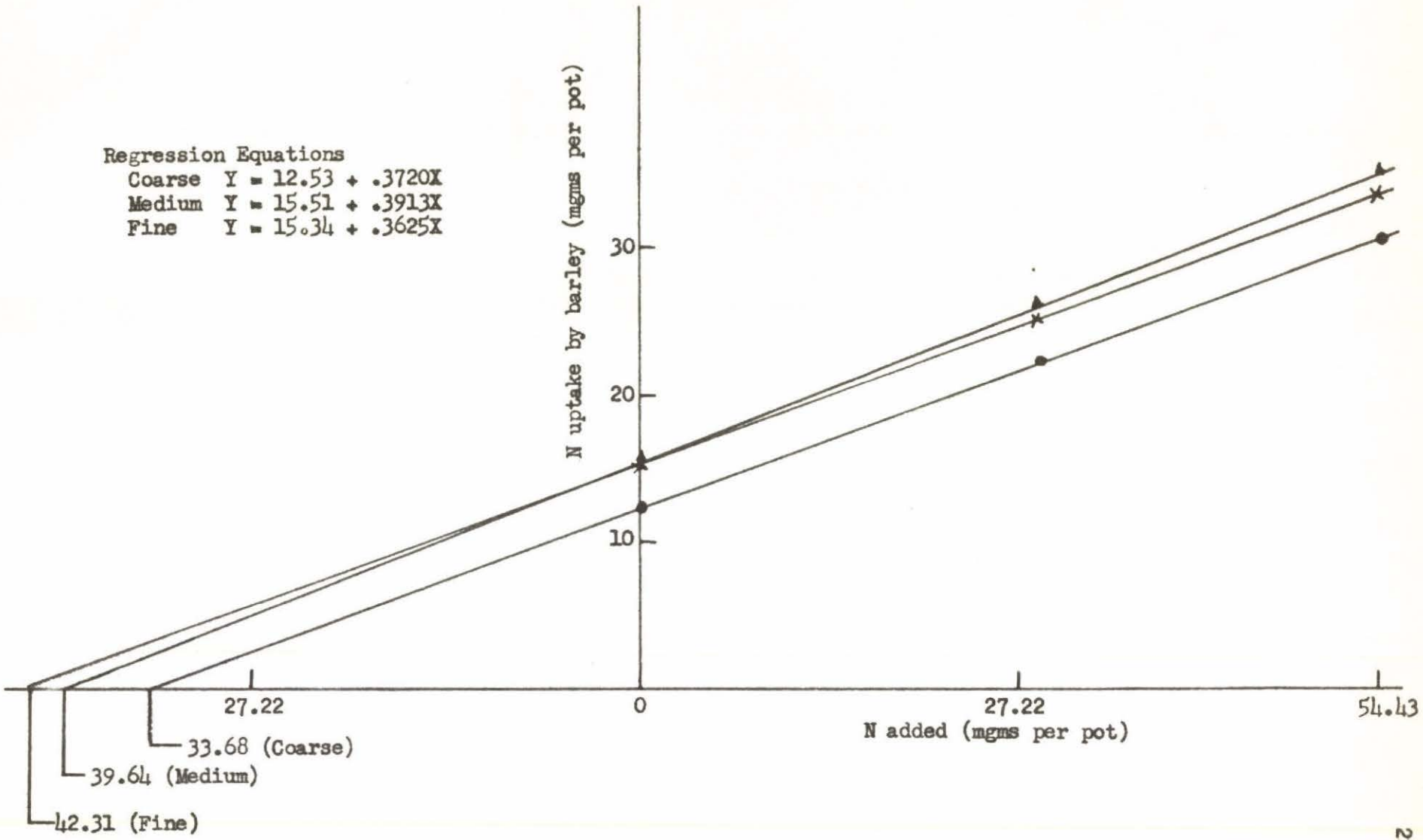

Figure 3. Theoretical N-values of soils of fine, medium, and coarse textures

decomposed than the alfalfa stubble.

The N-values for texture are as they might be expected, i.e., the coarser textures somewhat lower than the medium and fine textures.

The results of the analysis of variance on the dry weight yields of the plant tissue in the greenhouse experiment are presented in table 4.

Table 4. Analysis of variance of the dry weight yields of the barley plants in the greenhouse experiment

Source of variation	Degrees of freedom	Mean squares	F.
Soils	110	0.6617	0.804
Crops	3	3.3893	4.119**
Textures	2	2.4692	3.001*
Crops and textures	6	9.6133	11.682**
Treatments	2	17.7494	21.569**
Linear	1	33.6061	40.839**
Quadradic	1	1.5091	1.834
Error	220	0.8229	
Pots treated alike	999	0.0295	

** Significant at the 1 percent level
* Significant at the 5 percent level

There is considerable variation among pots treated alike. The coefficient of variation (18.64 percent) is somewhat high, indicating that the reliability of the yield data furnished by the greenhouse experiment leaves a lot to be desired. It should also be remembered that with a large number of observations, components exhibiting considerable variation may still be highly significant statistically.

CONCLUSIONS

The results of this study strongly indicate that the soil tests studied are inadequate for measuring the nitrogen supplying power of the irrigated soils of northern Utah. The low correlation coefficients between the soil tests and the nitrogen yields of the unfertilized pots indicated that less than 16 percent of the variation in the nitrogen yields can be accounted for by the soil tests. This, of course, is too low to be of value in making fertilizer recommendations.

The results of this study also indicate that the incubation method as described by Stanford and Hanway (14) does not work on the soils studied. It is quite evident that a means of providing for a more uniform physical condition of the soil samples during incubation is needed. The use of a bottle-type incubation method may overcome this difficulty.

From the results of this study it may be concluded that there is very little advantage among the two hydrolyzation methods and the total nitrogen and organic carbon measurement as to their ability to measure the nitrogen supplying power of the soil.

While the use of an acid digestion preceding the alkaline hydrolyzation did increase the amounts of nitrogen released, the results have little advantage over the other methods studied. However, because of the limited application of this idea in this study, such evidence is not conclusive. In future work with alkaline hydrolyzation methods, this idea should be more thoroughly investigated. The results of this study also indicate that the relationship between the $KMnO_4$ - soil ratio and ammonia released during the hydrolyzation process needs a more careful

exploration.

Data obtained in this study suggest that the nitrogen status of soils following a crop of corn may have been underestimated in the past--particularly on well-managed farms. It also appears that the value of alfalfa as a previous crop may be a little exaggerated. Yet, admittedly, the 44-day growing period used and limited growth conditions in this experiment would be quite inadequate to assess fully the value of alfalfa as a previous crop.

Because of the large discrepancies between the results of this study and the results of other workers on similar studies (13, 17) and because of the questionable quality of the greenhouse experiment, the results of this study should not be considered conclusive. Both hydrolyzation methods should be more thoroughly investigated. However, the failure of the incubation method in this study and similar results by Kadhim (11) on the same types of soil seem to indicate that future studies involving the incubation method as described by Stanford and Hanway (14) would have little value.

Perhaps in the future more importance should be placed on the evaluation of the effect of past cropping and fertilizing history, texture, and any other factors that might effect the nitrogen status of the soil. This information along with the future crop needs may have to serve as a basis for making fertilizer recommendation for some time to come. However, such information will not replace the need for knowing the soil nitrogen status <u>per se</u>, and only with the use of a good soil test can this be determined.

SUMMARY

1. The need for a laboratory method of determining the nitrogen supplying power of soils of irrigated farms of Utah is keenly felt. A study was conducted during 1957 and 1958 to evaluate methods of measuring the nitrogen supplying power of the soils in this area with the hope it may lead to more efficient use of fertilizer.

2. One hundred and eleven soil samples were collected from irrigated soils of northern Utah. These represented coarse, medium, and fine textured soils, and also soils whose previous crop was beets, corn, alfalfa, or grain.

3. A greenhouse experiment using 111 soil samples was conducted in November of 1957. The experiment included three levels of nitrogen (0, 60, and 120 pounds per acre) with four replications--a total of 1332 pots. Barley was grown in 2½-ounce Dixie cups and the fresh plant tissue weight, dry plant tissue weight, and nitrogen uptake were determined.

4. Total nitrogen, organic carbon, incubation, Kresge-Merkle hydrolyzation, and acid-alkaline hydrolyzation determinations were made on the 111 soil samples. These results were correlated with the nitrogen uptake by the barley plants grown in a greenhouse experiment. It was found that the acid-alkaline test values had the best correlation ($r = .3862$) followed by correlation coefficients of .3728 for the Kresge-Merkle hydrolyzation test values, .3666 for the total nitrogen test values, .3579 for the organic carbon test values, and .2105 for the incubation test values. The results of the total nitrogen determinations

were correlated with the results of the other determinations and r-values of .9845 for organic carbon test values, .8550 for acid-alkaline hydrolyzation test values, .8378 for the Kresge-Merkle hydrolyzation and .2340 for the incubation test values were found.

5. The effect of the past crop and soil texture was studied, and it was found that the soil following corn had the highest N-value but was only slightly higher than the N-values for soils following alfalfa and beets. The N-value for soil following grain was significantly lower. The fine textures had the highest N-value, followed by medium and coarse in that order.

6. Correlation coefficients of .9527 and .8956 were found for the correlation of fresh plant tissue weights and dry plant tissue weights with nitrogen uptake.

7. It was concluded that none of the methods studied is adequate for measuring the nitrogen supplying power of the irrigated soils in northern Utah.

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APPENDIX

Table 5. Location, texture, and previous crop of soil samples

Sample lab No.	County	Farmer	Texture	Previous crop
57-2100	Box Elder	Finn Gibbs	medium	grain
57-2101	--do--	Grant Nicholas	--do--	corn
57-2102	--do--	Bill Baty	--do--	beets
57-2103	--do--	--do--	--do--	alfalfa
57-2104	--do--	LaRue Yates	--do--	beets
57-2105	--do--	--do--	--do--	corn
57-2106	--do--	Lyman Chlarsen	--do--	alfalfa
57-2107	--do--	Shig Aoki	coarse	corn
57-2108	--do--	Horace Aoki	--do--	beets
57-2109	--do--	--do--	--do--	corn
57-2110	--do--	Clinton Burt	--do--	grain
57-2111	--do--	--do--	--do--	alfalfa
57-2112	--do--	G. M. Holmes	fine	grain
57-2113	--do--	Dan Baty	medium	--do--
57-2114	--do--	George Ross	fine	corn
57-2115	--do--	--do--	--do--	alfalfa
57-2116	--do--	--do--	--do--	beets
57-2117	--do--	Floyd Carter	coarse	alfalfa
57-2118	--do--	--do--	--do--	beets
57-2119	--do--	Ted Burt	fine	grain
57-2120	--do--	--do--	--do--	beets
57-2121	--do--	--do--	--do--	alfalfa
57-2122	--do--	Roy Bragger	coarse	grain
57-2123	Weber	Guy Genietti	--do--	corn
57-2124	--do--	--do--	--do--	grain
57-2125	--do--	--do--	--do--	alfalfa
57-2126	--do--	--do--	--do--	corn
57-2127	--do--	--do--	medium	alfalfa
57-2128	--do--	Bob Marigoni	--do--	beets
57-2129	--do--	--do--	coarse	--do--
57-2130	--do--	--do--	--do--	alfalfa
57-2131	--do--	--do--	--do--	grain
57-2132	--do--	--do--	medium	corn
57-2133	Davis	Jim Johnson	--do--	grain
57-2134	--do--	--do--	--do--	beets
57-2135	--do--	--do--	--do--	corn
57-2136	Weber	Larwence Muirbrook	coarse	beets
57-2137	--do--	Alvin East	fine	alfalfa
57-2138	--do--	Ezra Wayment	--do--	grain
57-2139	--do--	--do--	medium	alfalfa
57-2140	--do--	--do--	fine	grain
57-2141	Salt Lake	Rell Swenson	--do--	beets
57-2142	--do--	--do--	medium	alfalfa
57-2143	--do--	--do--	--do--	grain
57-2144	--do--	S. J. Godfrey	fine	alfalfa
57-2145	--do--	--do--	medium	corn
57-2146	--do--	Hugh Bringhurst	--do--	beets
57-2147	--do--	Smart Brothers	coarse	corn

Table 5. Continued

Sample lab No.	County	Farmer	Texture	Previous crop
57-2148	Salt Lake	Smart Brothers	coarse	alfalfa
57-2149	--do--	--do--	--do--	grain
57-2150	--do--	--do--	--do--	corn
57-2151	--do--	Frank Fritzgerald	fine	grain
57-2152	--do--	--do--	--do--	beets
57-2153	--do--	--do--	--do--	--do--
57-2154	--do--	Joseph Schmidt	medium	alfalfa
57-2155	--do--	--do--	--do--	grain
57-2156	Utah	Alfred Madsen	--do--	alfalfa
57-2157	--do--	--do--	fine	--do--
57-2158	--do--	--do--	medium	beets
57-2159	--do--	--do--	coarse	--do--
57-2160	--do--	--do--	--do--	alfalfa
57-2161	--do--	--do--	medium	grain
57-2162	--do--	Earl Stubbs	fine	beets
57-2163	--do--	--do--	--do--	--do--
57-2164	--do--	--do--	coarse	corn
57-2165	--do--	--do--	medium	--do--
57-2166	--do--	--do--	fine	--do--
57-2167	Cache	College Dairy Farm	medium	grain
57-2168	--do--	Mrs. G. J. Barker	coarse	beets
57-2169	--do--	--do--	--do--	corn
57-2170	--do--	--do--	--do--	alfalfa
57-2171	--do--	--do--	--do--	grain
57-2172	--do--	Mrs. Pond	--do--	corn
57-2173	--do--	--do--	--do--	grain
57-2174	--do--	--do--	--do--	alfalfa
57-2175	--do--	Lew Judd Allsop	--do--	beets
57-2176	--do--	College Dairy Farm	medium	alfalfa
57-2177	--do--	--do--	fine	corn
57-2178	--do--	Russell Selman	--do--	grain
57-2179	--do--	Joseph Anderson	--do--	alfalfa
57-2180	--do--	--do--	--do--	grain
57-2181	--do--	C. R. Anderson	--do--	beets
57-2182	--do--	--do--	--do--	alfalfa
57-2183	--do--	College North Farm	medium	corn
57-2184	--do--	--do--	--do--	grain
57-2185	--do--	--do--	--do--	alfalfa
57-2186	--do--	--do--	--do--	beets
57-2187	--do--	College South Farm	fine	corn
57-2188	--do--	Fuhriman	--do--	beets
57-2189	--do--	Marion Chugg	medium	--do--
57-2190	--do--	--do--	--do--	corn
58-742	Davis	Harris Adams	fine	alfalfa
58-743	--do--	--do--	--do--	grain
58-744	--do--	--do--	--do--	--do--
58-745	--do--	--do--	medium	alfalfa
58-746	--do--	--do--	fine	grain

Table 5. Continued

Sample lab No.	County	Farmer	Texture	Previous crop
58-747	Davis	Evans	medium	corn
58-748	--do--	--do--	--do--	grain
58-749	--do--	Melvin Robbins	--do--	beets
58-750	Cache	--do--	coarse	alfalfa
58-751	--do--	--do--	medium	corn
58-752	--do--	Wilford Zaugg	coarse	beets
58-753	--do--	--do--	--do--	corn
58-754	--do--	--do--	--do--	alfalfa
58-755	--do--	--do--	--do--	grain
58-756	--do--	--do--	--do--	alfalfa
58-757	--do--	--do--	--do--	beets
58-758	--do--	--do--	medium	--do--
58-759	--do--	--do--	fine	corn
58-760	--do--	--do--	--do--	alfalfa
58-761	Box Elder	Wilbur Baty	--do--	corn

Table 6. Test values for nitrogen on all the soil samples and nitrogen uptake by barley in the greenhouse

Soil lab number	Total N	Acid-alkaline hydrolyzation	Kresge-Merkle hydrolyzation	Organic carbon	Incubation	Nitrogen uptake by barley		
						N_0	N_1	N_2
	p.p.m. N	p.p.m. N	p.p.m. N	percent	p.p.m. NO_3-N	mgm./pot	mgm./pot	mgm./pot
2100	1765	635	180	2.28	62	14.5	31.2	41.3
2101	1685	602	167	2.07	41	11.8	20.0	37.0
2102	1515	580	164	1.67	48	13.3	29.4	45.9
2103	1215	513	138	1.46	45	16.1	19.8	39.8
2104	3475	617	202	3.39	50	22.7	34.9	36.4
2105	1820	618	166	1.98	44	22.7	36.2	45.5
2106	1020	448	129	1.17	47	14.5	21.1	35.4
2107	620	302	104	0.67	32	6.3	17.4	27.7
2108	810	450	115	1.02	50	20.2	28.2	31.5
2109	835	390	119	0.96	36	8.6	22.3	33.9
2110	880	373	117	1.02	35	8.7	22.9	28.7
2111	950	455	124	1.14	54	19.3	33.1	45.5
2112	1380	498	136	1.52	64	17.6	33.1	38.7
2113	1095	473	127	1.27	46	11.2	26.1	41.3
2114	1465	502	136	1.68	63	18.3	27.1	38.6
2115	1625	487	143	2.03	50	18.0	31.5	38.6
2116	1500	477	127	1.89	51	13.1	25.6	31.6
2117	855	398	118	0.90	50	13.2	20.8	33.1
2118	725	228	109	0.77	31	8.8	22.0	30.5
2119	1145	438	133	1.36	46	14.9	30.4	43.4
2120	1160	407	109	1.34	45	28.8	41.8	47.9
2121	1175	443	138	1.27	68	15.3	24.0	32.4
2122	560	250	95	0.55	39	6.0	18.3	32.7
2123	552	280	105	0.65	26	16.4	24.5	38.1
2124	495	210	90	0.59	22	11.1	23.7	18.4
2125	700	295	95	0.77	29	14.9	31.3	39.2
2126	860	395	105	1.01	45	24.7	22.7	29.7

Table 6. Continued

Soil lab number	Total N	Acid-alkaline hydrolyzation	Kresge-Merkle hydrolyzation	Organic carbon	Incubation	Nitrogen uptake by barley		
						N_0	N_1	N_2
	p.p.m. N	p.p.m. N	p.p.m. N	percent	p.p.m. NO_3-N	mgm./pot	mgm./pot	mgm./pot
2127	785	415	112	0.83	45	28.3	24.3	45.6
2128	795	345	107	0.95	38	8.3	19.1	35.6
2129	555	245	95	0.58	39	7.8	15.5	26.2
2130	545	255	92	0.59	51	14.5	21.6	38.4
2131	445	190	80	0.51	24	3.5	10.0	17.2
2132	905	370	107	1.03	36	13.6	29.4	38.1
2133	1115	465	112	1.24	36	13.7	23.4	38.4
2134	1075	515	112	1.14	68	14.6	28.8	34.8
2135	1060	405	125	1.14	41	21.1	34.7	37.6
2136	655	280	95	0.66	36	6.9	14.9	29.4
2137	1970	630	147	2.43	46	15.5	23.2	32.9
2138	1730	530	112	2.05	62	8.0	13.8	22.0
2139	1405	480	115	1.64	39	16.5	26.4	35.9
2140	1515	470	115	1.90	51	11.7	18.7	28.0
2141	860	475	112	1.04	63	7.1	20.5	28.2
2142	1200	440	140	1.27	67	16.4	31.1	38.4
2143	1172	470	125	1.25	54	14.6	24.9	34.7
2144	1605	560	158	1.80	4	13.1	31.0	48.8
2145	1480	595	130	1.60	91	23.9	37.1	45.3
2146	1420	580	142	1.42	95	29.1	48.9	48.8
2147	1365	530	122	1.57	55	11.1	15.5	36.1
2148	640	335	82	0.69	38	10.7	24.9	31.4
2149	1055	480	130	1.29	51	9.2	19.3	32.9
2150	1005	490	105	1.31	41	6.6	10.7	17.0
2151	1305	485	121	1.41	32	17.3	31.1	35.8
2152	1805	635	147	2.02	5	39.2	50.2	62.0
2153	1480	595	130	1.60	91	16.0	22.4	35.4
2154	610	280	95	0.65	34	9.1	20.0	30.7

Table 6. Continued

Soil lab number	Total N	Acid-alkaline hydrolyzation	Kresge-Merkle hydrolyzation	Organic carbon	Incubation	Nitrogen uptake by barley		
						N_0	N_1	N_2
	p.p.m. N	p.p.m. N	p.p.m. N	percent	p.p.m. NO_3-N	mgm./pot	mgm./pot	mgm./pot
2155	1090	440	120	1.07	65	5.2	14.6	26.9
2156	2290	575	132	3.30	39	17.0	28.5	34.2
2157	2200	525	142	2.76	59	8.8	19.9	25.0
2158	1690	530	142	2.06	37	12.0	26.1	39.4
2159	460	200	82	0.52	28	8.6	20.2	34.4
2160	887	430	110	1.02	41	8.7	20.2	28.7
2161	1420	470	120	1.73	30	11.8	22.6	34.2
2162	2690	725	190	3.48	65	16.4	24.0	41.6
2163	1920	610	165	2.60	79	31.5	45.5	58.2
2164	1065	560	92	1.06	48	12.0	34.3	38.6
2165	1750	600	158	2.26	52	32.7	43.3	50.7
2166	2660	715	192	3.57	6	27.8	40.9	49.4
2167	1605	610	142	2.07	53	10.6	16.4	33.9
2168	685	295	102	0.74	38	8.5	17.4	22.2
2169	792	360	108	0.96	28	6.1	16.7	29.7
2170	700	300	102	0.73	38	17.0	29.2	43.2
2171	625	310	85	0.77	26	12.7	25.5	32.3
2172	810	415	105	1.00	45	16.1	29.2	41.3
2173	785	370	102	0.94	54	15.9	27.6	37.6
2174	815	390	105	1.03	51	20.3	33.8	42.0
2175	710	305	102	0.77	55	9.7	24.2	39.7
2176	1740	605	165	1.92	57	19.3	32.9	41.7
2177	1515	555	142	1.53	24	10.4	24.5	38.6
2178	1175	540	85	1.54	61	8.1	18.6	29.5
2179	1410	500	140	1.81	36	13.0	24.4	38.4
2180	1285	505	132	1.45	27	7.8	21.3	28.1
2181	1185	505	142	1.20	10	9.9	12.2	30.0
2182	890	435	110	0.85	32	10.2	17.6	35.6

Table 6. Continued

Soil lab number	Total N	Acid-alkaline hydrolyzation	Kresge-Merkle hydrolyzation	Organic carbon	Incubation	Nitrogen uptake by barley		
						N_0	N_1	N_2
	p.p.m. N	p.p.m. N	p.p.m. N	percent	p.p.m. NO_3-N	mgm./pot	mgm./pot	mgm./pot
2183	1371	530	125	1.49	58	5.3	14.0	25.4
2184	1140	475	118	1.30	48	13.7	20.9	36.9
2185	1390	959	135	1.53	43	12.3	22.7	21.0
2186	1425	430	132	1.60	53	8.4	19.6	31.0
2187	1382	550	115	1.64	58	10.9	13.6	24.4
2188	1392	430	140	1.61	55	8.0	10.2	25.1
2189	1510	620	160	1.74	54	12.6	28.9	38.2
2190	1665	590	180	2.09	82	17.3	28.2	37.4
742	1270	515	127	1.44	67	19.0	24.3	40.2
743	970	375	102	1.07	32	12.3	13.5	28.0
744	930	375	92	1.10	48	9.8	22.2	25.8
745	1340	490	107	1.67	13	16.8	30.9	41.5
746	1420	485	115	1.78	52	13.2	26.8	38.2
747	845	385	100	1.06	52	6.1	20.3	21.3
748	875	425	92	1.13	36	7.5	22.5	29.8
749	960	480	110	1.05	55	12.2	19.2	19.8
750	925	430	125	1.13	50	13.7	28.3	34.5
751	1255	480	127	1.43	72	18.2	35.7	36.4
752	1130	415	107	0.99	68	26.4	40.8	48.1
753	495	220	98	0.51	29	10.2	10.6	33.1
754	490	235	92	0.64	29	10.8	26.7	31.1
755	600	280	95	0.50	30	5.5	6.6	17.8
756	610	270	105	0.89	52	28.4	28.2	36.1
757	665	330	102	0.86	40	11.1	25.7	35.9
758	1110	445	108	1.25	34	17.3	31.2	37.9
759	1095	455	115	1.31	39	26.7	29.8	32.1
760	1255	470	128	1.49	27	7.2	14.6	18.8
761	1935	600	110	2.72	54	20.6	19.2	36.2