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An Evaluation of Variation in Soil Test Results Caused by Sampling Methods and Individual Samplers

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AN EVALUATION OF VARIATION IN SOIL TEST RESULTS CAUSED BY

SAMPLING METHODS AND INDIVIDUAL SAMPLERS

BY

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SAMPLING METHODS AND INDIVIDUAL SAMPLERS

This thesis is approved as a creditable and independent investigation by a candidate for the degree, Master of Science, and is acceptable as meeting the thesis requirements for this degree. Acceptance of this thesis does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

Date

Date

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INTRODUCTION

Soil sampling has been a subject of much study over the past years and has been undertaken for many different purposes. In the agricultural industry, soil sampling is undertaken mostly for the sake of evaluating soil fertility potentials to aid in making fertilizer recommendations.

The need for better soil sampling is illustrated by the fact that inadequate sampling often leads to improper use of fertilizer by farmers. The samples are collected and brought to the soil testing laboratories where they are chemically analyzed for the main plant food elements. Fertilizer recommendations based on the soil test results may either be an aid or hindrance to the farmer depending on whether or not the samples represented the soils in the fields.

The present outcry against indiscriminate use of fertilizer as a source of water pollution dictates a need for research to develop techniques and methods of soil sampling which would enable farmers to collect representative samples. This in turn would lead to appropriate fertilizer recommendations.

At present, there are many methods and techniques which are being used in collecting soil samples. The main purpose of this study was to evaluate the variation in soil test results caused by individual samplers and to see if the use of appropriate sampling directions can reduce this variation.

REVIEW OF LITERATURE

The selection of a soil sample that represents the soil in which the sampler is interested has been the objective of many researchers during the past few decades. In reading through the literature, one soon realizes that the subject of soil sampling has been tackled with a wide range of purposes. This has led to many different, and at times, conflicting conclusions.

Soil Variability

Soil variability is a factor which affects soil test results. Jackson (8) pointed out that due to soil variability it is not possible to develop an entirely satisfactory method and procedure of soil sampling. Bear and McClure (1) agreed that on account of soil variability the method of sampling plots for chemical analyses could never be standardized. Hammond (5) reported that soil heterogeneity is not uniform. He suggested that a choice between a multistage and a simple random sampling scheme should be considered on the basis of the major topographic differences in the field.

Post (13) studied the problem of soil variability using statistical methods. He collected 81 samples from field plots sampling both surface and subsurface soils. The samples were analyzed for nitrogen content. He reported that the high variation in the nitrogen content was due to soil variability. This led to the conclusion that the field that looks uniform topographically may still have high variability. He concluded that statistical constants calculated for one area may not serve for others, and that a composite sample is of value only after the

soil variability has been determined. McKenzie (11) reported that the chemical composition of soil varies from place to place, though the soil may appear uniform. He pointed out that the sampling variation occurring in a small area of an apparently uniform soil is one of the variations which occurs between and within great soil groups and even soil types.

The problem of the influence of soil variability on optimum fertilizer use was studied by Jensen (9). His work showed that intensive field sampling provided a source of empirical evidence regarding methods of stratifying fields for purposes of fertilizer use. He pointed out that the natural basis for field stratification may prove inferior to simple alternative procedures which ignore soil types, slopes, and erosional differences. He stressed that variability of soil test quantities within a field may not necessarily increase with greater topographical differences. Such variability may be somewhat larger for gently rolling loess and glacial till soils than for soils of different origins having a broken and steep topography.

Sampling

Reed and Rigney (14) studied the problem of sampling soil from uniform and non-uniform fields each with similar soil types. They worked to isolate the major sources of errors in soil sampling and to evaluate the effects of reducing the magnitude of such errors. The sources of error under study included variations in the individual samples from the area to be characterized, variations in subsampling (that is, the individual samples drawn from the area), and variations accompanying the analytical procedure. They found that field variation was a limiting factor in determining the level of accuracy in soil

sampling test results.

Cochran (4) used a statistical approach in evaluating the soil sampling problem. He stressed that everyone should try to obtain accurate and representative samples. A representative sample can be obtained by giving every unit in the population an equal chance of being included in the sample, and accuracy of a sample can be increased by careful planning. He stipulated that the size and structure of the sampling unit is important in determining accuracy of sampling.

Cline (2) outlined the principles of soil sampling as a guide to sampling soil for many objectives. He pointed out that the results of chemical analyses of soil specifically defined the characteristic of a small subsample. It provides an accurate definition of the soil in the field only if the gross sample is representative of the soil from which the subsample had been drawn. He pointed out that the probable errors for sampling and sample treatment were greater than for subsampling and analytical method. He stressed that the limits of accuracy were determined by subsampling rather than by the analysis. Subdividing the fields into uniform strata was suggested as an effective measure to increase accuracy of sampling. It was stipulated that mixing soils of dissimilar horizons leads to conflicting soil test results. Cline (3) emphasized that in taking soil samples to measure soil fertility the top 15 cm should be sampled separately from the lower horizons.

Bear and McClure (1) suggested that in presenting the results of soil chemical analyses, the method employed in choosing the samples should be clearly stated. They stressed that a definite plan should be worked out before selecting soil samples from fertility plots. The

plan should include the program for choosing the composite samples that would adequately represent the plots. This implies a definite number of borings from within the field to be composited.

Voss and Pesek (17) carried out an elaborate greenhouse experiment to estimate and relate soil test values and units of added fertilizer as a means of predicting crop yields. It is thought that this method will be invaluable when fully developed and refined in correlating soil test and fertilizer recommendations to the potential yield capacity of the soil and crop.

Sampling Equipment and Methods

Cline (3) worked with methods of collecting and preparing soil samples, and made the following recommendations: (a) sampling tools should provide uncontaminated samples; (b) spot checking of the field using a spade to examine the horizonal variation should be carried out before actual sampling (this should include observation of unusual spots in the field); (3) note the history of the past treatment of the field; and (4) sample the field in a stratified order to obtain a representative soil Sample, be considered it essential to have a complete randomization of the sampling units.

Welch and Fitts (18) at North Carolina State University investigated the problem of sampling equipment as one of the factors affecting soil test results. Twenty-six fields were selected for the study. Common sampling tools used were: sampling tube, auger, spade, and narrow trowel. The fields were sampled at the following depths:

0 to 8, 8 to 15, and 15 to 23 cm. As expected, not much variation was observed due to use of individual tools.

Keller, et al. (10) conducted an experiment to obtain information concerning relative efficiency of various methods of sampling. They used soil organic matter content and pH values of soil taken from hop yards in the states of Oregon and Washington. They reported that the most efficient method for sampling hop yard soils for the determination of organic matter content and pH values was to include a maximum number of samples within each field. To supply recommendations for the area, one should take samples from a large number of locations with a minimum number of samples per location.

Hemingway (7) made a study on soil sampling errors and reported that methods and procedures of sampling were sources of errors in the analysis of soil samples. He pointed out that distance between sampling sites has no influence on the sampling errors. It was discussed that intensive sampling to provide reliable means does not necessarily reflect the true status of the soil if the soil variability from point to point is considerable.

Hayes (6) of North Carolina State University conducted an empirical investigation of sampling methods for an area. The objective was to find a systematic method which would simplify the physical act of locating the site of sampling units. The study involved 14 fields and 4 methods, namely: random, stratified random, systematic zig-zag, and systematic grid. He reported that the stratified random method was superior to others.

Onate (12) worked with methods of sampling soils from replicated field experiments. He aimed at obtaining information on the variation among composites of soil with different numbers of borings and variation within such composites. He reported that the most efficient sampling scheme for an experimental site consisted of taking a single composite containing as many individual borings as needed to obtain precision desired.

METHODS AND MATERIALS

Location of Cooperator Fields

Four fields were selected for this study. They belonged to farmers at different locations. Three of the fields were located in Brookings County and the other field in Deuel County. The fields varied in size from 5.7 to 56.7 hectares.

The soils from within these locations represent some of the major agricultural soils of this area. Most of them were developed under the influence of tall grasses in calcareous parent material of various depths. The Royce Emerick field and part of the Cecil Hall field are somewhat poorly drained (Figures 2 and 3). The Royce Emerick field is located within the Deer Creek flood plain, while the eastern section of the Cecil Hall field is flat with almost zero percent slope. The individual fields are described under separate headings.

Location I, Section 35 T111N R50W

The field sampled from this location belonged to Duane Colburn of Brookings County. It is located 6.4 km north of the 6th Street and Medary Avenue intersection in Brookings, South Dakota, and 0.8 km west on north side of the road. It was a large field, about 56.7 hectares. The field landscape was somewhat irregular with slopes of 2 to 6 percent (Figure 1). It was cropped with rye during 1970.

The major soil types within the area sampled included the Vienna loam, gently sloping soil, which occupied most of the southern section of the field in association with Lismore silty clay loam and Brookings silty clay loam soils in the somewhat poorly drained positions. The

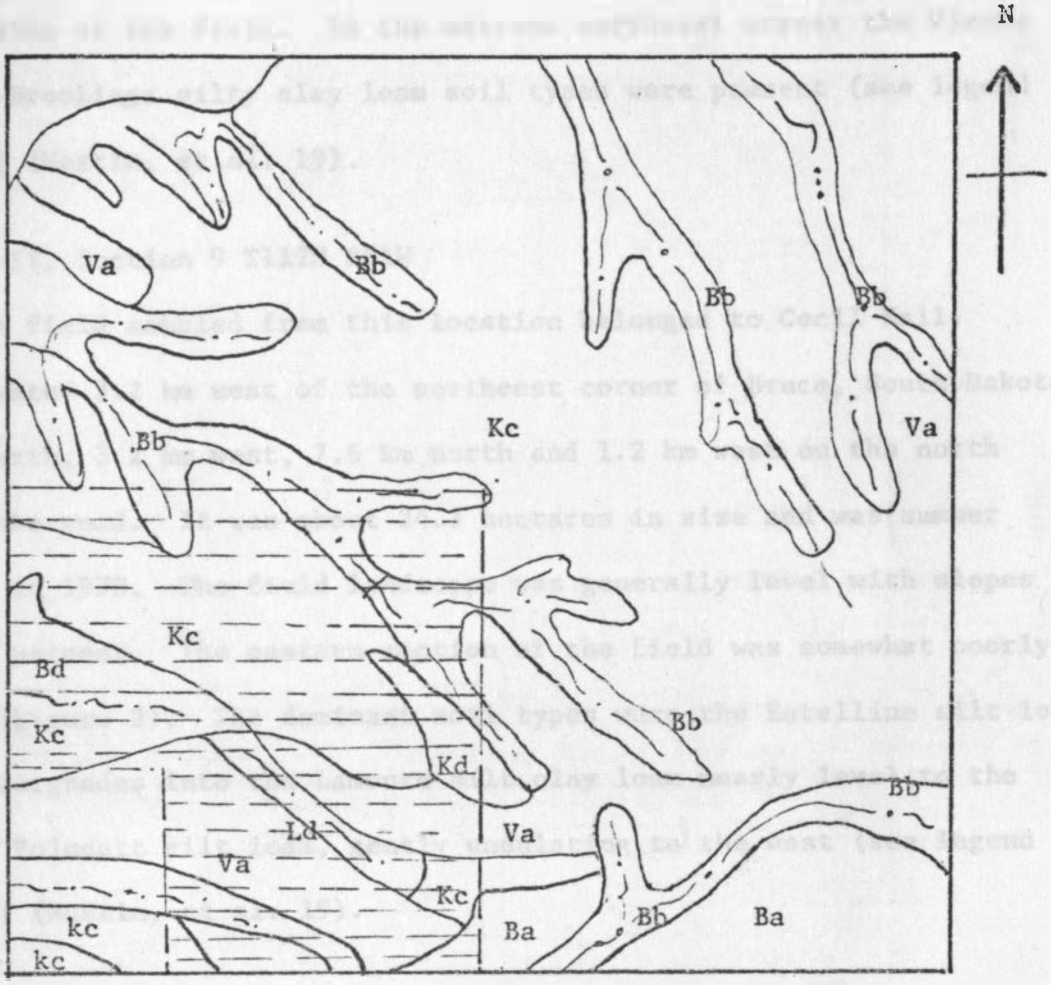


Figure 1. Location I. Section 35 T111N R50W
Field 1. Duane Colburn. Showing soil types within the location and the area sampled (56.7 hectares)

Legend:

Bb=Brookings silty clay loam, drainage way
Kc=Kranzburg silt loam, nearly level
Kd=Kranzburg silt loam, sloping
Ld=Lismore silty clay loam, drainage way
Va=Vienna loam, gently sloping

Kranzburg silt loam, nearly level soil, dominated the central part of the field and intergraded into Kranzburg silt loam, sloping soil on the eastern side of the field. In the extreme northwest corner the Vienna loam and Brookings silty clay loam soil types were present (see legend Figure 1) (Westin, et al. 19).

Location II, Section 9 T112N R51W

The field sampled from this location belonged to Cecil Hall. It is located 3.2 km west of the northeast corner of Bruce, South Dakota, 3.2 km north, 3.2 km west, 7.6 km north and 1.2 km west on the north side of the road. It was about 24.3 hectares in size and was summer fallowed in 1970. The field landscape was generally level with slopes of 0 - 2 percent. The eastern section of the field was somewhat poorly drained (Figure 2). The dominant soil types were the Estelline silt loam which intergrades into the Lamoure silt clay loam nearly level to the east and Poinsett silt loam, gently undulating to the west (see legend Figure 2) (Westin, et al. 19).

Location III, Section 20 T110N R49W

The field sampled from this location belonged to Royce Emerick. It is located 7.6 km east of 6th Street and Medary Avenue intersection in Brookings, South Dakota, and 0.4 km north on west side of the road. It was about 6.1 hectares in size. The field was within the Deer Creek flood plain. It was generally flat and somewhat poorly drained. It was cropped with small grain during the 1970 season.

The major soil types within the area sampled were the Lamoure silty clay, nearly level soil, which intergrades into the Salomon clay

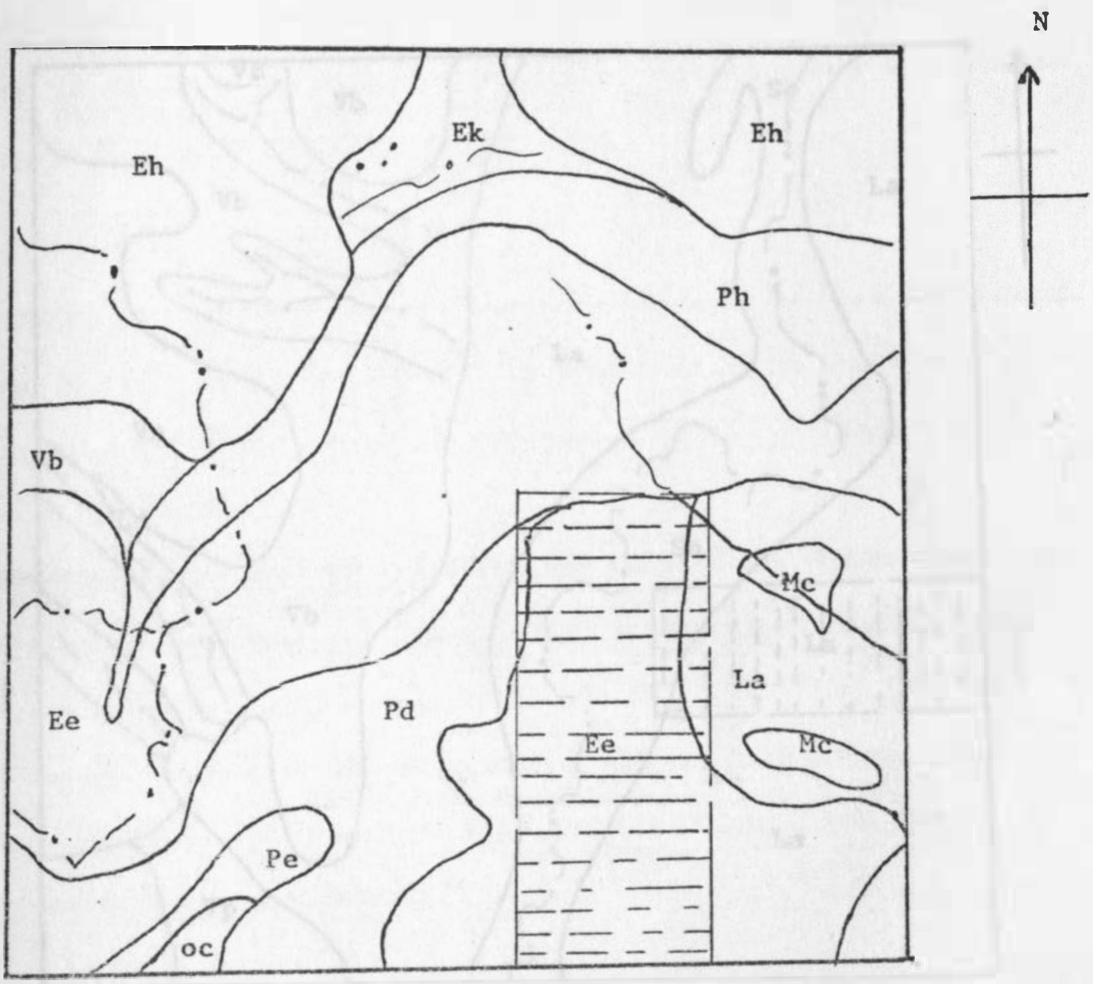


Figure 2. Location II. Section 8 T112N R51W
Field 2. Cecil Hall. Showing soil types within the location and area sampled (24.3 hectares)

Legend:

Ee = Estelline silt loam, moderately shallow
La = Lamoure silty clay loam, nearly level
Pd = Poinsett silt loam, gently undulating

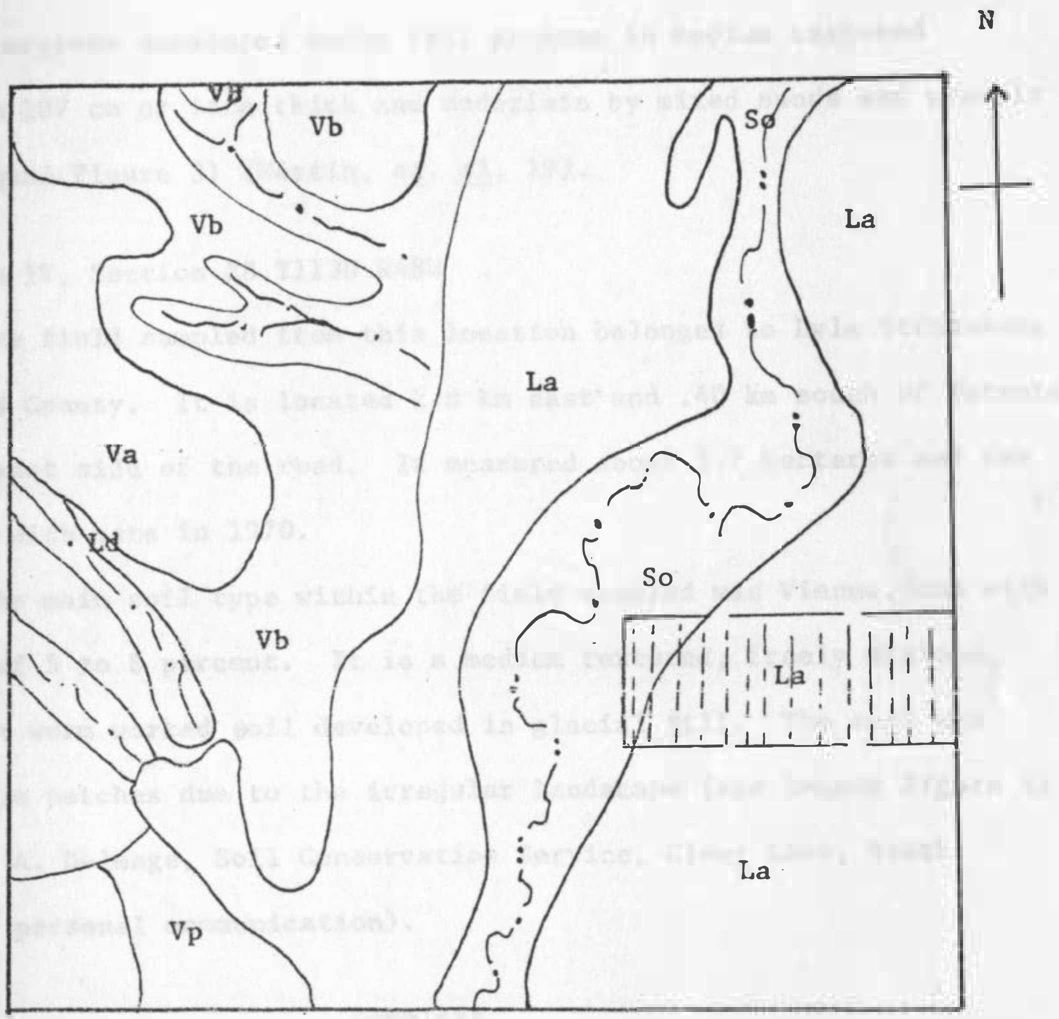


Figure 3. Location III. Section 20 T110N R49W
Field 3. Royce Emerick. Showing soil types within the location and area sampled (6.1 hectares)

Legend:

La = Lamoure silty clay loam, drainage way

So = Solomon clay, nearly level

soil on the west side (Figure 3). Both Lamoure silty clay loam and Solomon clay are members of the somewhat poorly drained Chernozem-Humic Gley intergrade developed under tall grasses in medium textured alluvium 107 cm or more thick and underlain by mixed sands and gravels (see legend Figure 3) (Westin, et. al. 19).

Location IV, Section 28 T113N R48W

The field sampled from this location belonged to Lyle Strassberg of Deuel County. It is located 2.8 km east and .40 km south of Toronto on the east side of the road. It measured about 5.7 hectares and was cropped with oats in 1970.

The main soil type within the field sampled was Vienna loam with slopes of 5 to 8 percent. It is a medium textured, freely drained, somewhat worm worked soil developed in glacial till. The soil was eroded in patches due to the irregular landscape (see legend Figure 4) (Mr. F. A. Delmage, Soil Conservation Service, Clear Lake, South Dakota, personal communication).

Samplers

Seven men participated in the soil sampling operation. The men were drawn from farming communities, local fertilizer dealers, and students from South Dakota State University. This was carried out in accordance with the scope of the experiment to determine variations among soil samples collected by different persons under a given condition and to evaluate the hypothesis that, "it does matter who samples the field," and "it does matter what sampling technique is used." The men were:

Terensio Opio, a graduate student at SDSU and the author of this paper.

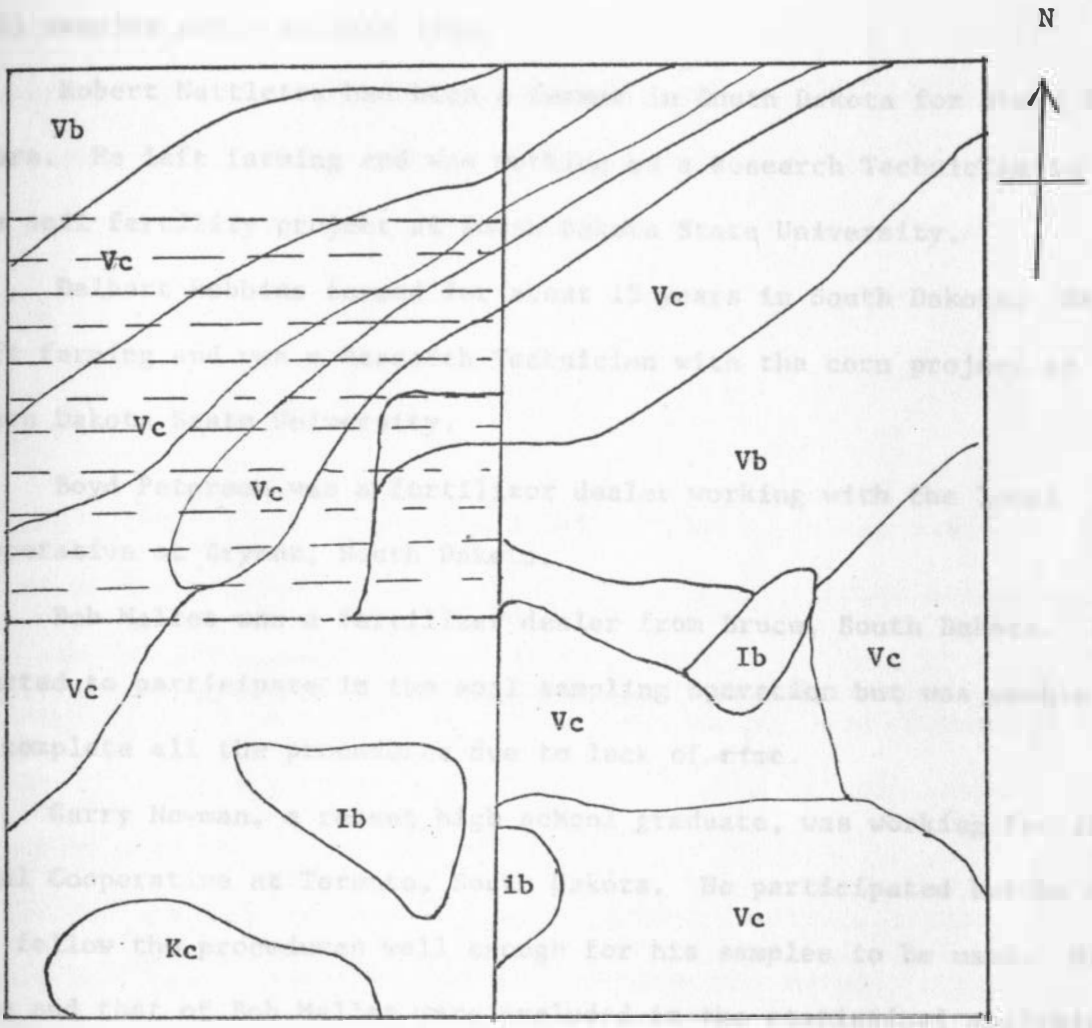


Figure 4. Location IV. NW 1/4 of Section 28 T113N R48W
Field 4. Lyle Strassberg. Showing soil types within the location and the area sampled (5.7 hectares)

Legend:

Vc = Vienna loam sloping

Marty Kloster, a senior student at South Dakota State University. He had been assisting in the Soil Testing Laboratory, but had not taken soil samples prior to this time.

Robert Nettleton had been a farmer in South Dakota for about 25 years. He left farming and was working as a Research Technician in the soil fertility project at South Dakota State University.

Delbert Robbins farmed for about 13 years in South Dakota. He left farming and was a Research Technician with the corn project at South Dakota State University.

Boyd Peterson was a fertilizer dealer working with the local Cooperative at Bryant, South Dakota.

Bob Mallet was a fertilizer dealer from Bruce, South Dakota. He started to participate in the soil sampling operation but was unable to complete all the procedures due to lack of time.

Garry Newman, a recent high school graduate, was working for the local Cooperative at Toronto, South Dakota. He participated but he did not follow the procedures well enough for his samples to be used. His data and that of Bob Mallet were excluded in the statistical analysis of the overall experimental data.

Sampling Procedures

The procedures used in collecting soil samples for this study were divided in two phases using five different sampling methods.

Phase I

Method I

Simple random method was used for collecting soil samples from

selected fields. This constituted method number one. Six men carried out the sampling operation. No instructions were given. The men were provided with locations of the fields from which they were to collect soil samples. They carried out the sampling operation individually. When the soil samples were brought to the Soil Testing Laboratory, each sampler completed a form specifying the procedure he used. This included sampling depth, tool used in the fields, and number of samples taken.

Phase II

Sample collecting in this phase was carried out using simple instructions as outlined in Appendix A. These were prepared and given to each sampler after completing phase I.

Sampling depth was kept at 15 cm. The sampling tube used was marked at 15 cm depth to remind the samplers to collect soil samples to this level.

For the remaining methods of sampling each composite sample consisted of 25 separate cores which were thoroughly mixed. A sample was drawn from this mixture, placed in a paper bag and labeled immediately. The samples were brought to the Soil Testing Laboratory at South Dakota State University by the samplers.

Method II. Random Sampling

A 20 cm stick was used to locate the site for taking individual soil cores. It was flipped into the air and allowed to fall at random. The sample was collected from the marked end of the stick. Twenty-five individual samples were collected. Details of the procedures are found

in Section II and Figure I of Appendix A.

The techniques followed in stratification of the fields were based on major topographical differences. In addition, soil types were used to a limited extent in identifying soil differences by some of the samplers.

Method III. Stratified Systematic Zig-Zag Method

The procedures adopted by all samplers in the deployment of the stratified systematic zig-zag method are illustrated in Section III and Figure 2 of Appendix A.

Method IV. Systematic Grid Method

Each field was arbitrarily divided into four equal parts. Each quarter partition was sampled as illustrated in Figure 3 of Appendix A. Details of the procedures used are found in Section IV of Appendix A.

Method V. Stratified Random Sampling

Individual stratum within each field was determined by slope, soil, and drainage differences. Details of the procedures used are found in Section V and Figure 4 of Appendix A.

Sample Preparation

The soil samples were delivered to the Soil Testing Laboratory where they were promptly logged in to avoid confusion. They were air-dried in aluminum foil plates in the conditioning cabinet overnight. The air was drawn in by a fan and was warmed by four-300 watt flood lamps before passing over the samples. The dried samples were crushed with a Nasco-Asplin Soil Grinder and sieved through a 2 mm screen.

Chemical Analysis

Each sample was tested by using standard methods adopted by the Soil Testing Laboratory at South Dakota State University. The tests were: soil organic matter, water-soluble nitrates, available phosphorus, available potassium, soil pH and soluble salts.

Organic matter content was determined by the chromic acid method as outlined by Jackson (8).

Soil pH was determined on a 1:1 soil-water suspension using a glass electrode.

Soluble salts were determined on the filtrate of the 1:1 soil-water suspension using a Solu-Bridge Soil Tester Model RD-26, calibrated for direct reading as mmho/cm (15).

Available phosphorus was determined by the Bray and Kurtz No. 1 Method which makes use of the .03$\underline{N}$ NH_4F and .025$\underline{N}$ HCl extracting solution as outlined by Jackson (8).

Available potassium was determined by the 1$\underline{N}$ ammonium acetate method (8). The concentration of the potassium was determined with the Perkin-Elmer flame photometer.

Water-soluble nitrate-nitrogen was determined by a modified phenoldisulfonic acid method (8).

Statistical Analysis

The data were statistically analyzed using methods outlined by Steel and Torrie (16). The data were processed through an IBM 360 Model 40 computer with Memory size 128K at South Dakota State University. Dr. W. L. Tucker, Experiment Station Statistician, helped in arranging

and supervising the processing of the data through the computer in the Research and Data Processing Department.

RESULTS AND DISCUSSION

The results and discussion of this study are presented as main effects and interactions. The main effects (cooperator fields, tests, samplers, and methods) will be discussed in light of the results of the statistical analyses as summarized in Table 1. Presentation of the interaction effects will follow. Original data will be presented and discussed in view of significant differences as revealed by the analysis of variance F-tests which are tabulated in Table 1. The discussion will be within the scope of the main objective which was to evaluate variations among samples collected by individual persons. The range of chemical analysis results for soil samples collected by various methods and by individual persons for each field are presented in Appendix B (Tables 1, 2, 3, and 4).

Main Effects

Cooperator Fields

The fields were shown to be significantly different for all tests. This was expected. The comparative test results for the four fields are summarized in Table 2.

The four fields sampled for the study were from different locations and each had more than one soil type. They differed in major topographical and erosional differences (see Methods and Materials).

The Cooperator field 1 (Colburn), 3 (Emerick), and 4 (Strassberg) were cropped with small grains in 1970. Cooperator field 2 (Hall) was summer-fallowed in 1970. This produced higher

Table 1. F-test values for the analysis of variance of the six soil tests

Source[1]	df	Organic Matter	Nitrate-Nitrogen	Available Phosphorus	Available Potassium	pH	Soluble Salts
Total	538			F-Test Values			
C	3	265.78**	1004.82**	308.22**	241.75**	1103.60**	186.03**
T	1	.22ns	.26ns	.52ns	.52ns	4.78*	3.82ns
CT	3	1.16ns	.00ns	.94ns	.64ns	.28ns	.33ns
S	4	19.37**	41.69**	6.38**	30.21**	7.33**	2.65*
CS	12	5.08**	14.97*	3.08**	4.12**	2.05*	2.32*
TS	4	.29ns	.07ns	.43ns	.33ns	.00ns	.50ns
CTS	12	.54ns	.07ns	.10ns	.15ns	.13ns	.62ns
M	4	1.28ns	7.19**	.29ns	2.84**	5.71**	1.62ns
CM	12	1.17ns	1.96*	1.22ns	1.06ns	1.84*	1.98*
TM	4	.21ns	.08ns	.05ns	.06ns	.01ns	.55ns
CTM	12	.21ns	.08ns	.09ns	.09ns	.20ns	.31ns
SM	16	1.68*	2.67**	1.73**	5.43**	2.81**	3.12**
CSM	48	1.16ns	2.70**	2.26**	1.91**	1.23ns	2.11**
TSM	16	.21ns	.08ns	.06ns	.08ns	.17ns	.44ns
TCSM	48	.17ns	.12ns	.07ns	.10ns	.12ns	.38ns
Residual	338						

[1]Where C = Cooperator fields
T = Test (duplicate samples)
S = Sampler
M = Method
** = P .01
* = P .05
ns = not significant

nitrate-nitrogen (Table 2). Field 2 also tested higher in phosphorus and potassium than other fields.

Field 3 (Emerick) tested highest in organic matter and lowest in soluble nitrates. It was a bottomland soil and somewhat poorly drained. The low test values of nitrate-nitrogen obtained on this field and on field No. 1 and 4 may be attributed to crop uptake of nitrate. Field No. 3 also showed the highest pH and soluble salts. This was probably due to poor drainage and possibly due to inherent soil genetic properties.

Table 2. Mean soil test results showing variations among cooperator fields

Field	Organic Matter %	Nitrate-Nitrogen ppm N	Available Phosphorus kg of P/ha	Available Potassium kg of K/ha	pH	Soluble Salts mmho/cm
1	3.7	11	17	319	6.7	.33
2	4.0	43	30	410	7.5	.55
3	4.9	10	7	289	8.0	.62
4	4.1	13	17	262	6.5	.33

Tests

A duplicate test was performed on each soil sample. The analysis of variance indicated that there were no significant differences between duplicate tests except for pH (Table 1). The reason for the significant difference between the pH duplicates is obscure. The laboratory test results showed that variation between the two tests was usually ±.1 of a pH unit. An example of the original data for the two duplicate pH

values among samples collected by Sampler No. 4 is illustrated in Table 3. By examination of this table one can see the tendency for t_2 to show a higher value (14 out of 21 observations).

Table 3. The average pH values obtained by two duplicate runs on each sample collected by sampler No. 4 showing variation between the two tests

Method	Field 1 t_1	Field 1 t_2	Field 2 t_1	Field 2 t_2	Field 3 t_1	Field 3 t_2	Field 4 t_1	Field 4 t_2
1	6.7	6.8	7.7	7.7	8.0	7.8	6.5	6.7
2	6.4	6.5	7.4	7.5	7.9	7.8	6.3	6.5
3	6.8	7.0	7.5	7.5	7.9	7.8	6.4	6.5
4	6.6	6.8	7.4	7.5	7.9	8.0	6.3	6.5
5	6.9	6.8	7.5	7.5	7.8	8.0	6.2	6.3

Where t_1 = 1st duplicate

t_2 = 2nd duplicate

The general mean test results showing some slight differences among the tests as indicated by duplicate 1 and 2 are summarized in Table 4.

Table 4. Mean test results showing variation due to analytical methods

Duplicate	Organic Matter %	Nitrate-Nitrogen ppm N	Available Phosphorus kg of P/ha	Available Potassium kg of K/ha	pH	Soluble Salts mmho/cm
1	4.1	19	17	319	7.1	.45
2	4.1	19	17	321	7.2	.46

Samplers

The analysis of variance indicated that there were highly significant differences among the samplers for each soil test (Table 1). This difference was anticipated for the men who participated in the sampling operation had different backgrounds as related to soil fertility and soil sampling. The purpose of the study was centered on these differences and development of a means of reducing such differences.

The general mean test results showing differences among samplers for all methods and fields are presented in Table 5. The data collected by both Garry Newman and Bob Mallet were excluded as explained in previous paragraphs.

Table 5. Mean test results showing variations among samplers

Sampler	Organic Matter %	Nitrate-Nitrogen ppm N	Available Phosphorus kg of P/ha	Available Potassium kg of K/ha	pH	Soluble Salts mmho/cm
Nettleton	4.1	16	17	329	7.1	.45
Boyd	4.4	15	20	358	7.3	.42
Kloster	3.9	24	17	306	7.2	.48
Robbins	4.2	18	15	284	7.2	.46
Opio	4.1	22	17	323	7.1	.46

Samples taken by Sampler Boyd tested highest in organic matter, available phosphorus, available potassium and pH but tested lowest in nitrate-nitrogen and soluble salts (Table 5). On the average, the variations among the samplers were not consistent. For instance, Sampler Kloster's samples tested lowest in organic matter but attained highest

test values for soluble nitrates and soluble salts. Samples taken by Samplers 1, 4, and 5 came fairly close in most test results except for available potassium. This may be attributed to natural occurring variations within the fields.

Methods

The mean test results showing variations among methods of sampling are presented in Table 6. There are only slight differences in the test values due to methods used.

The analysis of variance (Table 1) indicated that differences among methods of taking soil samples were significant for soluble nitrate--nitrogen, available potassium, and pH. It is rather difficult to pinpoint the reason for such variation. Most likely this may be attributed to the high test values scored with method I where no instructions were provided (Table 6). Natural soil variability may also account for such differences. Samplers mixing soils of dissimilar horizons could also lead to variation in soil test results (2).

Interactions

Sampler X Method

It was planned that the main objective of the study could be achieved by using simple instructions for taking soil samples. The approach to the problem was undertaken in two phases. In the first phase, soil sampling was conducted without instructions. This resulted in samplers differing widely in the number of soil samples collected and brought to the Soil Testing Laboratory at South Dakota State University (Table 7).

Table 6. Mean test results showing variations among methods of soil sampling

Method	Organic Matter %	Nitrate-Nitrogen ppm N	Available Phosphorus kg of P/ha	Available Potassium kg of K/ha	pH	Soluble Salts mmho/cm
Random Sampling (without instruction)	4.2	16	17	336	7.1	.43
Random Sampling (with instruction)	4.1	19	17	311	7.2	.47
Stratified Systematic Zig-Zag	4.2	20	17	319	7.2	.44
Systematic Grid Method	4.2	20	17	316	7.2	.47
Stratified Random Sampling	4.1	20	17	319	7.2	.46

Table 7. Number of samples collected from different fields by different persons for simple random method without directions

Sampler	Field 1	Field 2	Field 3	Field 4
Nettleton	10	7	5	6
Boyd	1	2	1	1
Robbins	2	1	1	1
Kloster	2	2	2	3
Opio*	0	0	0	0
Mallet	3	2	1	1
Newman	1	1	1	1

*Sampler Opio did not participate in this sampling operation without instruction as he was the one who designed the procedure.

In the second phase the field notes provided by each sampler revealed that there was much variation among samplers in carrying out the sampling operation within the context of the instruction provided. The samplers varied in the deployment of stratified sampling methods (Methods III and V). This was probably due to their different interpretation and determination of major topographical criteria for stratifying the fields. The number of soil samples collected by the stratified methods varied with individual samplers and fields depending on the number of strata into which a field was divided. The results of the field stratification by individual samplers are summarized in Appendix C (Figures 1-4).

The sampling by randomized (Method II) and systematic grid (Method IV) methods did not result in variation insofar as the number of soil samples collected from individual fields was concerned.

There were highly significant differences as shown by analysis of variance for the interaction between sampler and method. This appears to support the null hypothesis that "it does matter who samples the fields" and "it does matter which technique is used".

A wide variation was observed among samples collected by individual samplers for each method. The patterns of variations in relations to samplers and methods are presented in Figures 5-16. The figures have been plotted from the general mean values of test results among samples collected by individual persons for all methods. The actual mean values are shown in Appendix D (Table 1).

It is apparent that the samplers' approach to Method I (without instructions) resulted in wide variations among samples collected by

Figure 5. Variations in Soil Organic Matter Mean Values of Samples Collected by Different Methods by Individual Persons.

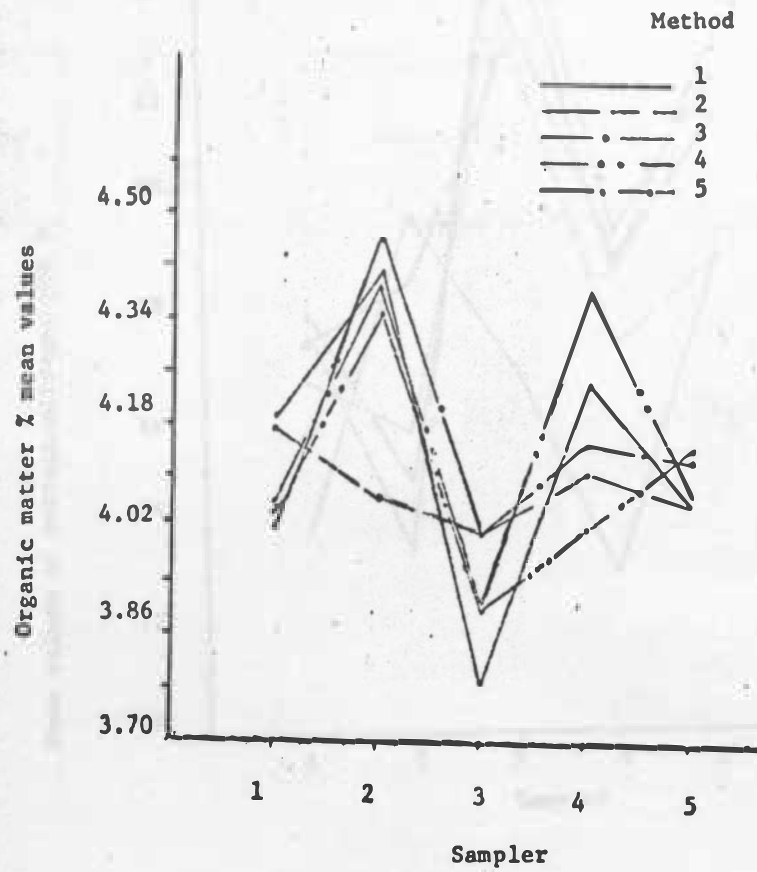


Figure 6. Variations in Soil Organic Matter Mean Values of Samples Collected by Individual Persons by Different Methods.

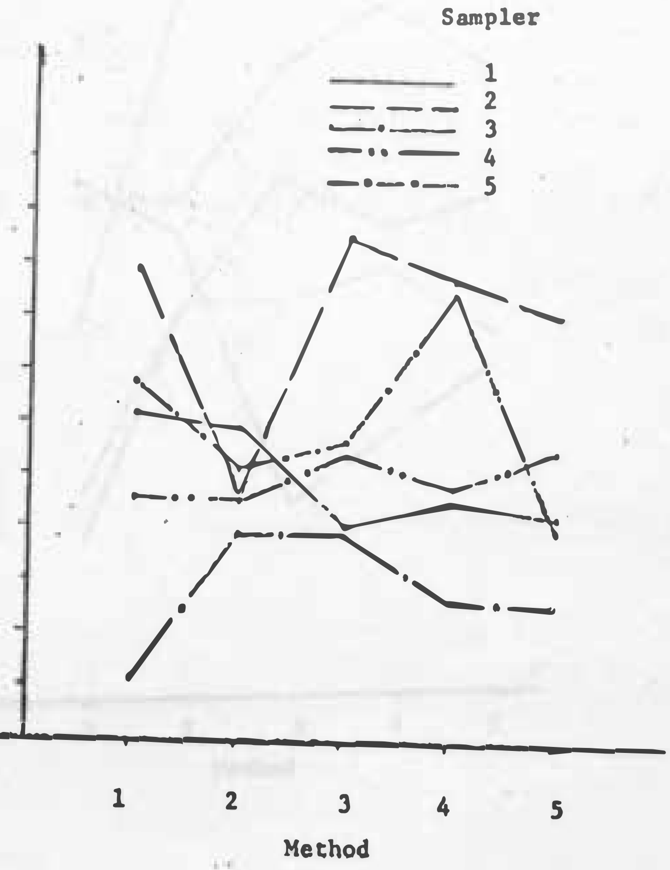


Figure 7. Variations in Soil Nitrate-Nitrogen Mean Values of Samples Collected by Different Methods by Individual Persons

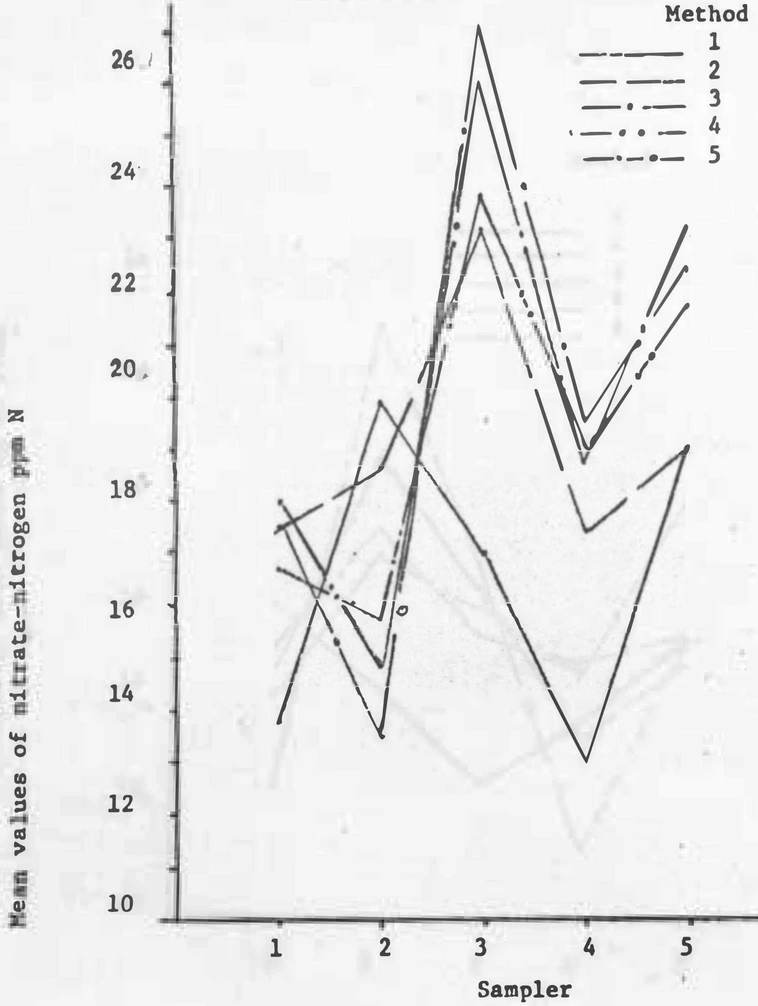


Figure 8. Variations in Soil Nitrate-Nitrogen Mean Values of Samples Collected by Individual Persons by Different Methods

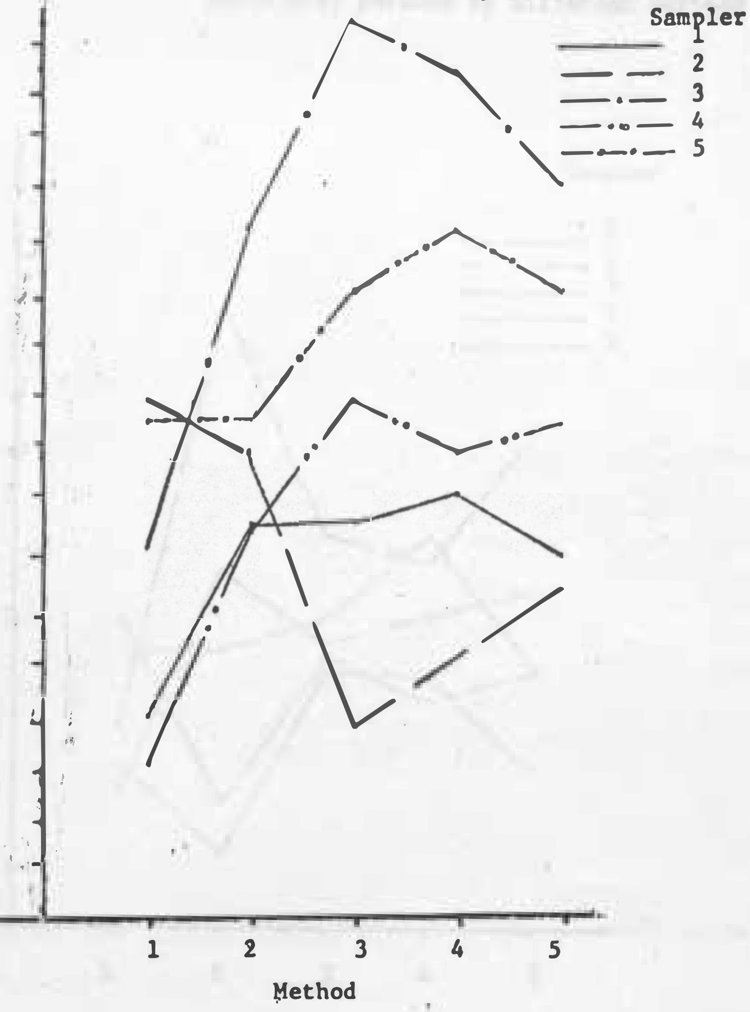


Figure 9. Variations in soil phosphorus mean values of samples collected by different methods by individual persons

Figure 10. Variations in soil phosphorus mean values of samples collected by individual persons by different method

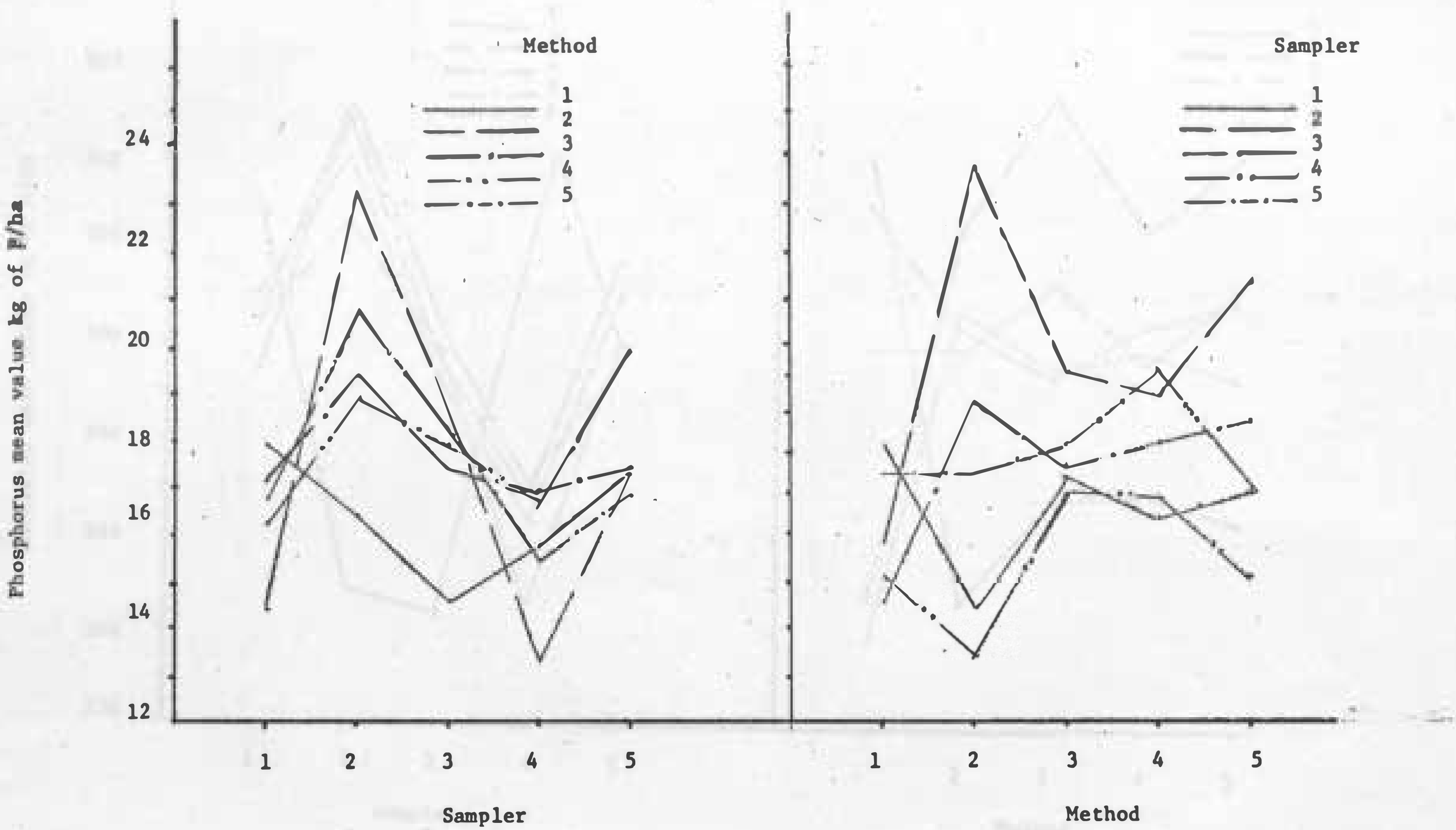


Figure 11. Variations in soil potassium mean values of samples collected by different methods by individual persons

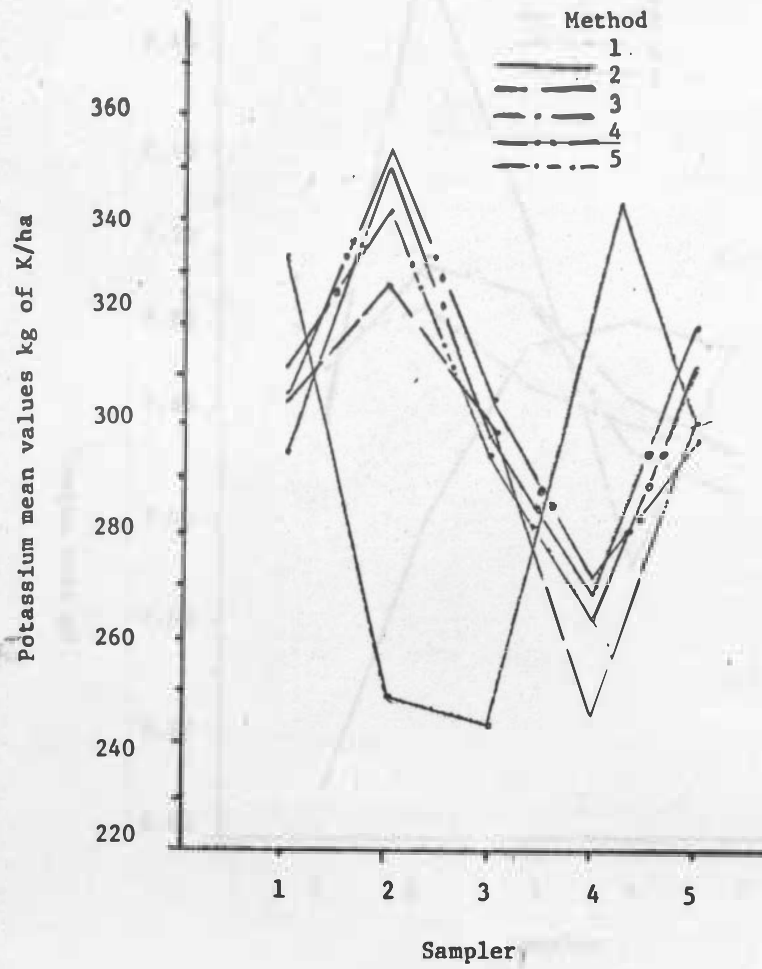


Figure 12. Variations in soil potassium mean values of samples collected by individual persons by different methods

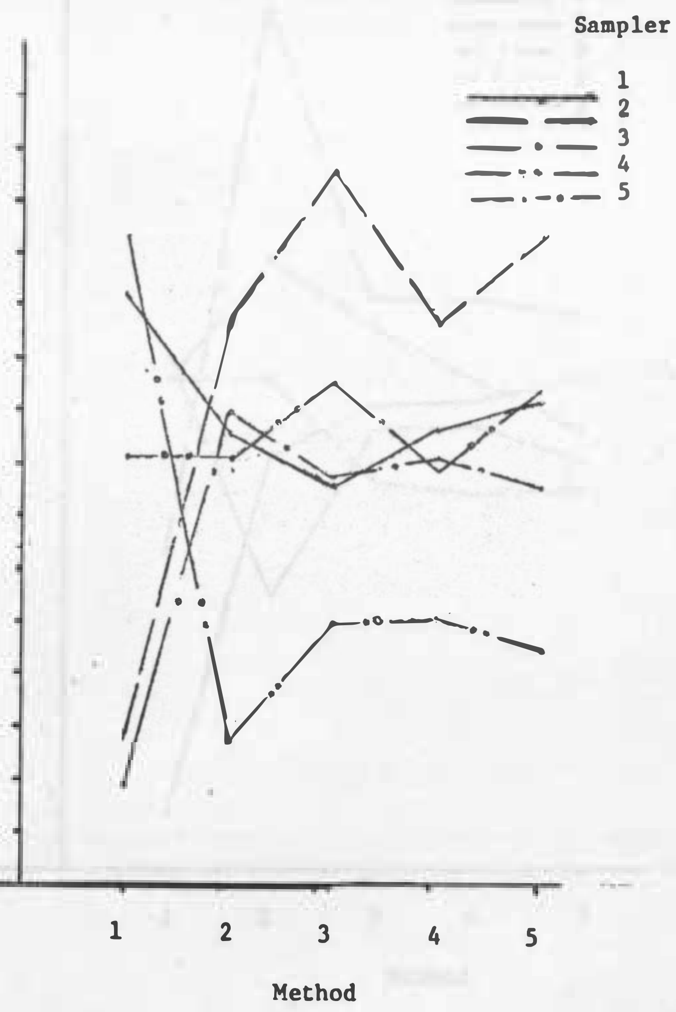


Figure 13. Variations in soil pH mean values of samplers collected by different methods and by individual persons

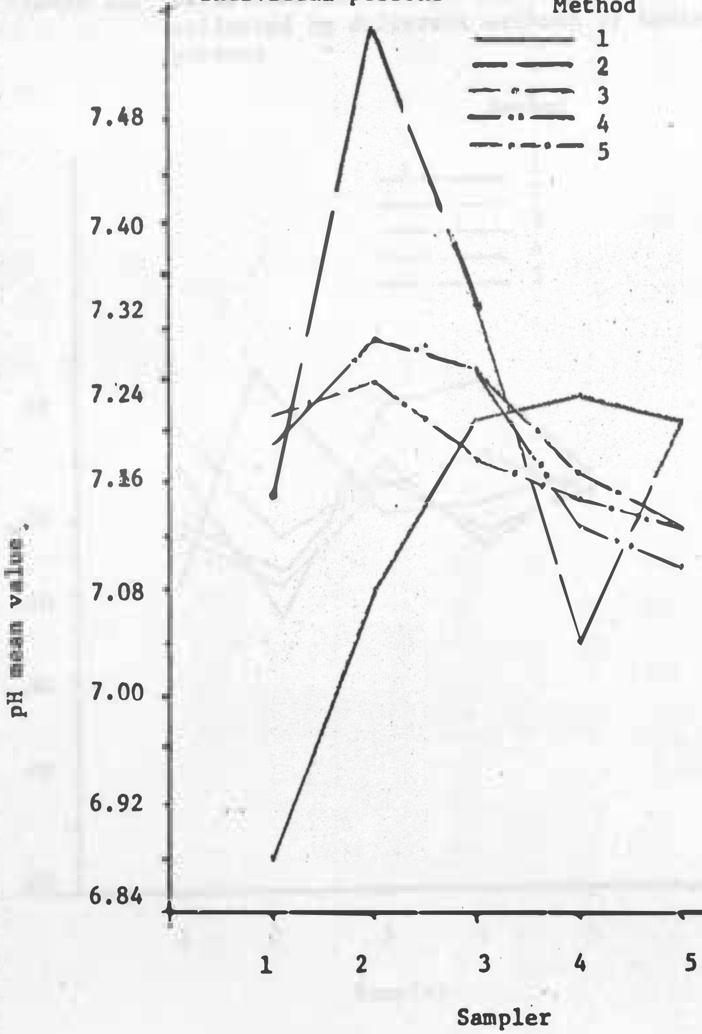


Figure 14. Variations in soil pH mean values of samples collected by individual persons by different methods

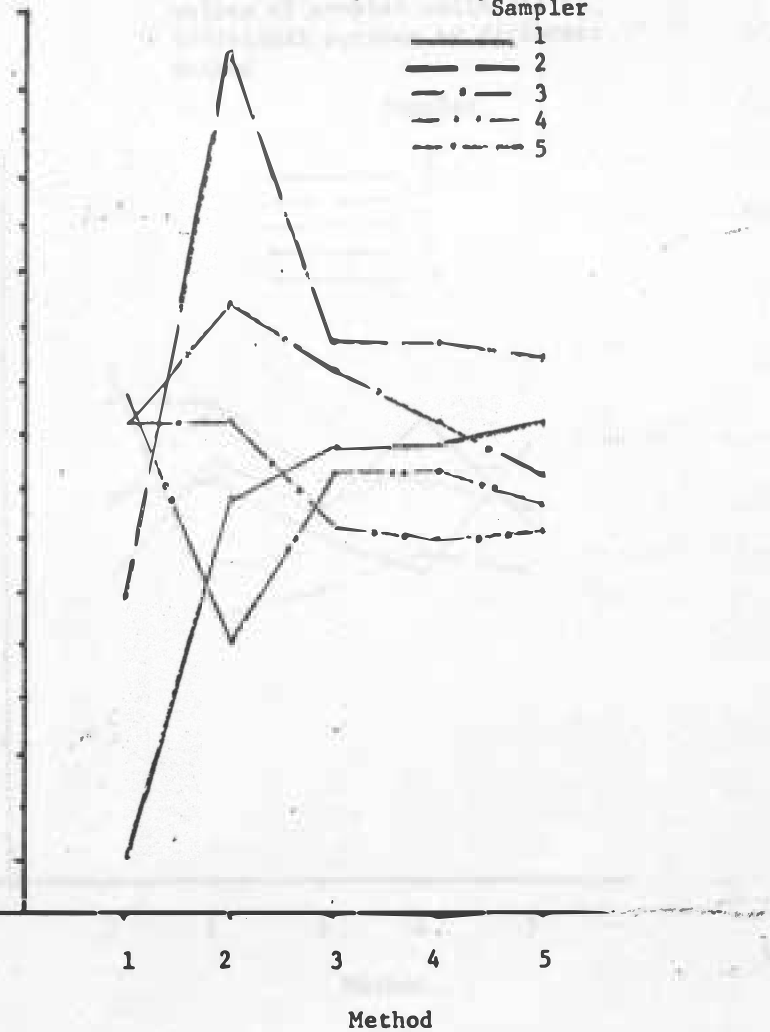


Figure 15. Variations in soluble salts values of samples collected by different methods by individual persons

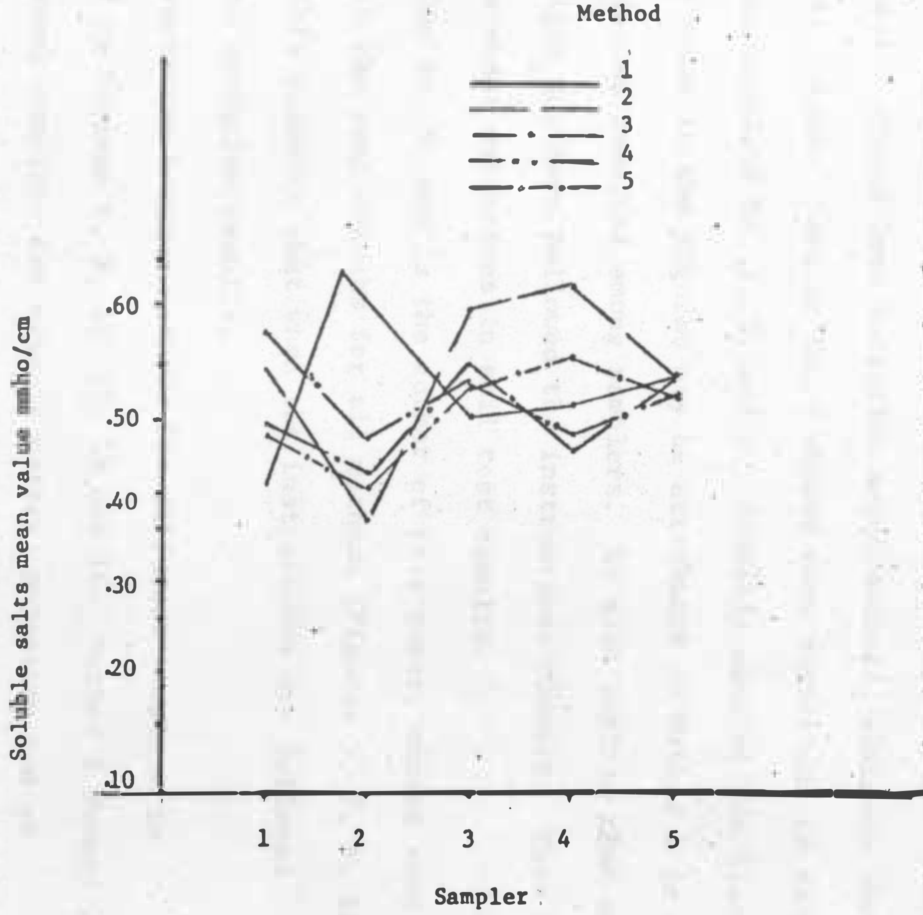
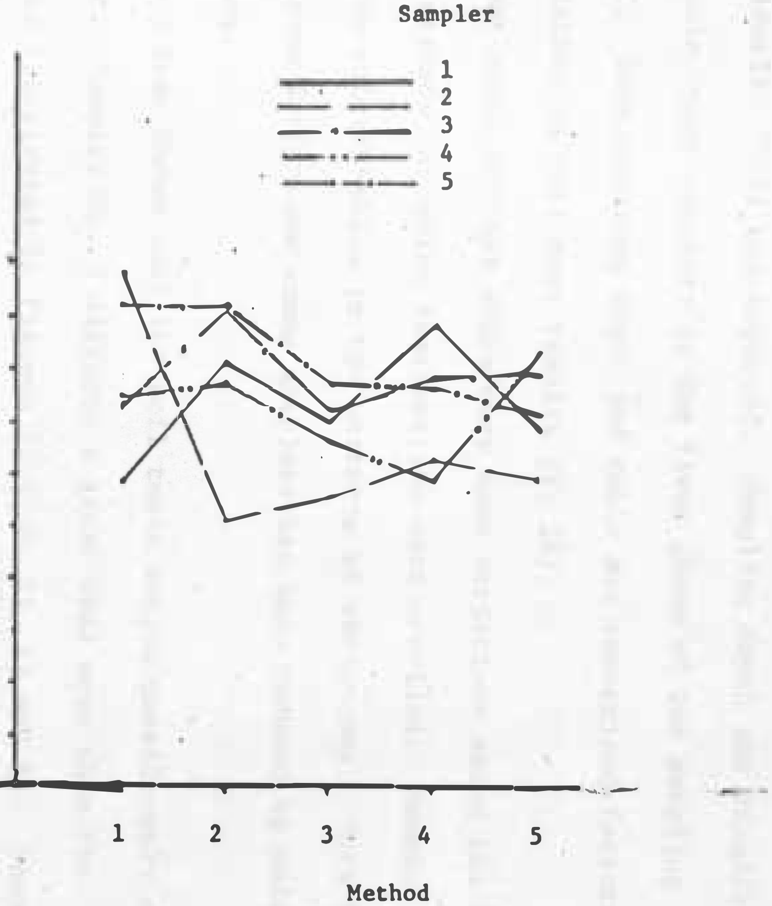


Figure 16. Variations in soil soluble salt mean values of samples collected by individual persons by different method



the individuals. This was expected. Sampling depth and sampling tools were variable among samplers in the first phase of the sampling experiment. Both sampling depth and tools are recognized factors which cause variation in soil test results (2, 18).

It was observed that there were some variations among the four remaining methods for which instructions were provided. However, they showed close relationships in the patterns of variations. This implies that the large variations among samplers had been reduced by using simple instructions.

It had been shown that the soil tests varied considerably due to the sampler. Sampler No. 2 differed a great deal more than the others as is illustrated in Figures 5, 7, 9, 11, 13 and 15. Samplers No. 1, 3, and 5 showed less variation among methods, although they differed in soil test values. Sampler No. 4 showed more variations in sampling methods than Samplers No. 1, 3, and 5. Probably some of the fluctuating variations shown in the figures may be attributed to Method I in which wide differences resulted among samplers. It also implies that some samplers might not have followed the instructions closely. This factor could cause wider variations in soil test results.

Sampler No. 5, who is the author of this paper, showed very little variation in the test results for all methods (Figures 5, 7, 9, 11, 13 and 15). This suggests that when the instructions are followed closely less variation results.

The variation between methods for different samplers is illustrated in Figures 6, 8, 10, 12, 14 and 16. Method I showed wide variation among samplers for organic matter, potassium and pH

(Figures 6, 12 and 14) but showed somewhat less variation among samplers in test values for soluble nitrates, available phosphorus, and soluble salts (Figures 8, 10, and 16).

Method II appears to show less variation among samplers for test value of organic matter, soluble nitrates, and to a lesser extent in soluble salts (Figures 6, 8, and 16). But wide variations were observed among samplers in the test values of available phosphorus, pH, and available potassium (Figures 10, 12, and 14).

Method III showed wide variations in test values of organic matter, soluble nitrates, and available potassium (Figures 6, 8, 12), but variation was very much reduced in test values of available phosphorus, pH, and soluble salts (Figures 10, 14 and 16).

Method IV was quite variable among samplers for test values of organic matter, soluble nitrates, and potassium (Figures 6, 8, and 12) and showed less variation among samplers for test values of available phosphorus, pH, and soluble salts (Figures 10, 14, and 16).

Method V showed large variations for organic matter, soluble salts, nitrate-nitrogen, available potassium, and available phosphorus.

It may be suggested that such variations could have come about as a result of some samplers not being able to follow the instructions adequately. On the average, Method IV showed the least variation among samples. Both Methods I and II showed the largest variations followed by Methods III and V.

Cooperator Field X Test

The interaction between field and test showed no significant differences for all chemical soil tests.

Cooperator Field X Sampler

The analysis of variance indicated highly significant differences in chemical soil test results due to interaction between field and sampler. Both cooperator fields and samplers were found to be significantly different.

All chemical soil tests are summarized by sampler and field in Table 8.

A close examination of the data in Table 8 reveals that there were different magnitudes of variation among fields for various soil test results for individual samplers. For instance, in organic matter test Sampler No. 5 showed a small magnitude in variation among fields while Sampler No. 4 showed a large magnitude of variation among fields. Other samplers fall in between the range of the two magnitudes.

The test results for nitrate-nitrogen showed largest magnitude in variation of fields for Sampler No. 5, followed by Sampler No. 1. The smallest magnitude was shown for Sampler No. 2.

On the otherhand, Sampler No. 2 had the largest magnitude of variation among fields for available phosphorus test (Table 8).

Similarly, potassium test results indicated largest magnitude in variation among fields for Sampler No. 5 and Sampler No. 1.

Fields appeared to have a high magnitude of variation for pH and soluble salt test values for Sampler No. 1 and No. 5. It is apparent that Samplers No. 1 and No. 5 might have followed the instructions closely.

Table 8. Mean test results showing variations among samples collected by different persons among fields

Sampler	Field	Organic Matter %	Nitrate-Nitrogen ppm N	Available Phosphorus kg of P/ha	Available Potassium kg of K/ha	pH	Soluble Salts mmho/cm
Nettleton	1	3.7	9	17	331	6.5	.28
	2	3.8	44	25	415	7.6	.57
	3	4.9	6	7	304	7.9	.65
	4	4.0	9	17	262	6.4	.31
Boyd	1	3.8	10	17	356	6.8	.32
	2	4.1	28	37	447	7.5	.54
	3	5.1	13	5	324	8.1	.50
	4	4.4	10	20	311	6.7	.32
Robbins	1	3.4	15	17	321	6.8	.40
	2	3.8	52	27	370	7.4	.56
	3	4.7	11	10	287	8.0	.61
	4	3.9	18	17	254	6.6	.34
Kloster	1	3.5	12	15	249	6.8	.34
	2	4.0	40	27	373	7.6	.53
	3	5.2	10	5	272	7.9	.65
	4	4.0	11	17	240	6.4	.33
Opio	1	3.8	7	20	343	6.8	.31
	2	4.2	49	30	442	7.4	.53
	3	4.5	13	5	247	7.9	.70
	4	4.0	19	20	259	6.4	.33

Test X Sampler

The analysis of variance indicated that there was no significant difference in all the soil test results for the interaction between test and sampler (Table 1).

Cooperator Field X Test X Sampler

The three factors interacting did not produce any significant difference on the test results. Similarly, this applies to the interactions, test x methods, cooperator fields x test x methods, test x method x samplers, and test x cooperator field x sampler x method.

Cooperator Field X Method

The interaction between field and method showed no significant difference in the test results for organic matter, available phosphorus, and available potassium. There were significant differences in the test values for soluble nitrates, pH and soluble salts. It is suggested that this could be attributed to variation in sampling depths (especially in phase I of the sampling experiment). The general mean test results showing differences among samples and methods are presented in Table 9. The range in test results among fields for individual methods is small except for soluble nitrates, pH and soluble salts. For Field 1, the range in soluble nitrate was 9 to 16 ppm N, pH values ranged from 6.6 to 6.9, and soluble salt test results ranged between .32 and .35 mmho/cm. The range of test values within individual fields is variable.

The past treatment of the fields may also account for some variation in the test results among samples collected for individual methods. It was noted that the fields were cultivated with chisel implements during the course of the sampling operation. This undoubtedly interfered with sampling depth determinations among samplers.

Cooperator Field X Sampler X Method

The original data collected from each for the systematic grid method showed a relationship between field variability and variation among samples collected by individuals are summarized in Tables 10, 11, 12, and 13.

(Table 1). It is rather difficult to provide reasons for the test results not showing significant differences for organic matter and pH values.

Table 9. Mean test results showing variations of different methods among fields

Field	Method	Organic Matter %	Nitrate-Nitrogen ppm N	Available Phosphorus kg of P/ha	Available Potassium kg of K/ha	pH	Soluble Salts mmho/cm
1	1	3.7	9	17	316	6.6	.32
2	1	4.1	43	27	432	7.4	.52
3	1	5.0	5	10	309	7.8	.58
4	1	4.0	10	17	289	6.4	.30
1	2	3.5	10	15	333	6.9	.35
2	2	3.9	42	30	375	6.9	.58
3	2	4.9	11	7	282	8.0	.62
4	2	4.1	14	17	252	6.6	.35
1	3	3.7	12	17	316	6.7	.33
2	3	4.0	41	27	420	7.5	.53
3	3	4.8	13	7	277	8.0	.57
4	3	4.1	14	17	267	6.6	.34
1	4	3.7	12	20	316	6.6	.34
2	4	4.0	43	30	408	7.6	.51
3	4	4.9	11	5	287	8.0	.70
4	4	4.0	15	17	257	6.5	.35
1	5	3.7	16	17	316	6.7	.32
2	5	3.9	43	30	415	7.6	.58
3	5	4.7	11	5	279	8.0	.63
4	5	4.0	14	17	264	6.4	.30

The original data collected from each field for systematic grid method by individuals which showed relationship between field variability and variation among samplers collected by individuals are summarized in Table 10, 11, 12, and 13. The tables are arranged in four sections representing each quarter of the fields sampled. Each quarter portion

Table 10. Field 1. Duane Colburn. Average soil test results showing variations within the fields as collected by individual persons for systematic grid method

	Soil Tests[1]						Soil Tests					
	OM	NO_3	P	K	pH	Salt	OM	NO_3	P	K	pH	Salt
	NW 1/4						NE 1/4					
[2]												
A	3.9	13	17	333	6.5	.34	3.8	12	12	239	6.5	.53
B	3.8	13	20	333	6.5	.26	4.0	13	15	375	6.9	.32
C	3.4	16	20	281	6.5	.35	3.4	17	15	272	6.9	.46
D	3.8	16	12	212	6.2	.30	3.6	18	10	212	7.4	.48
E	3.6	7	15	254	6.5	.30	3.8	7	15	178	7.2	.45
	SE 1/4						SE 1/4					
A	3.6	8	15	341	6.5	.30	3.7	7	17	336	6.4	.30
B	4.1	12	20	442	6.5	.32	3.8	12	25	353	6.4	.30
C	3.5	16	37	395	6.9	.46	3.2	14	12	264	6.4	.30
D	3.9	11	22	245	6.7	.39	3.0	10	10	183	6.5	.29
E	4.0	15	64	215	6.6	.35	3.5	9	17	217	6.4	.27

[1] See previous table headings for expression of soil test units.

[2] Where A = Nettleton
B = Boyd
C = Robbins
D = Kloster
E = Opio

Table 11. Field 2. Cecil Hall. Average soil test results showing variations within fields as collected by individual persons for systematic grid method

	Soil Tests[1]						Soil Tests					
	OM	NO_3	P	K	pH	Salt	OM	NO_3	P	K	pH	Salt
	NW 1/4						NE 1/4					
A[2]	3.7	50	20	353	7.9	.70	3.6	45	20	442	7.5	.61
B	4.6	16	30	482	7.7	.31	4.2	18	27	432	7.6	.55
C	3.9	54	25	420	7.9	.60	3.4	53	25	412	7.5	.60
D	3.6	38	40	378	7.6	.52	4.1	45	42	341	7.1	.45
E	4.1	48	30	425	7.5	.45	3.9	45	25	380	7.4	.56
	SW 1/4						SE 1/4					
A	3.8	48	30	417	7.8	.36	3.9	41	25	390	7.5	.28
B	4.0	20	20	410	7.9	.50	4.4	25	30	472	7.8	.42
C	3.7	56	32	395	7.9	.60	4.0	25	27	408	7.6	.61
D	4.1	51	23	363	7.8	.52	4.6	62	37	343	7.3	.28
E	4.3	56	37	435	7.5	.53	3.9	46	30	420	7.3	.55

[1] See previous table headings for expression of soil test units.

[2] Where A = Nettleton
B = Boyd
C = Robbins
D = Kloster
E = Opio

Table 12. Field 3. Royce Emerick. Average soil test results showing variations within fields as collected by individual persons for systematic grid method

	Soil Tests[1]						Soil Tests					
	OM	NO_3	P	K	pH	Salt	OM	NO_3	P	K	pH	Salt
			NW 1/4						NE 1/4			
[2]												
A	4.8	13	7	267	8.0	1.45	5.5	7	12	383	8.0	.50
B	5.8	21	2	301	8.1	1.05	4.6	13	10	348	8.0	.79
C	4.9	13	5	326	8.1	.49	5.0	11	5	289	8.0	.66
D	5.7	8	1	274	8.0	.59	5.9	7	5	326	7.9	.59
E	4.6	16	3	240	8.0	.75	4.8	12	2	264	7.9	.70
			SW 1/4						SE 1/4			
A	4.7	8	10	311	8.0	.80	4.5	4	7	324	8.0	.91
B	5.4	16	3	274	8.2	.75	5.0	12	3	294	8.2	.28
C	4.2	10	7	282	8.0	.95	4.5	11	7	284	8.1	.35
D	4.8	7	2	242	8.0	.70	5.3	7	2	287	8.0	.57
E	4.5	10	5	274	8.1	.59	4.4	16	1	242	8.0	.80

[1] See previous table headings for expression of soil test results.

[2] Where A = Nettleton
B = Boyd
C = Robbins
D = Kloster
E = Opio

Table 13. Field 4. Lyle Strassberg. Average soil test results showing variations within fields as collected by individual persons for systematic grid method

	Soil Tests[1]						Soil Tests					
	OM	NO_3	P	K	pH	Salt	OM	NO_3	P	K	pH	Salt
[2]			NW 1/4						NE 1/4			
A	4.4	13.2	15	242	6.6	.36	4.3	9.4	17	284	6.4	.35
B	4.3	11.3	25	309	6.7	.30	4.3	16.5	27	363	6.6	.35
C	4.1	25.8	17	240	6.8	.40	4.1	20.9	15	294	6.3	.35
D	3.4	11.5	17	190	6.6	.29	4.0	16.7	27	208	6.4	.32
E	4.1	18.4	22	178	6.7	.39	4.3	26.0	22	217	6.2	.35
			SW 1/4						SE 1/4			
A	3.6	7.1	12	240	6.7	.38	3.6	7.1	12	240	6.7	.38
B	4.8	13.6	15	316	7.1	.50	4.8	13.6	15	316	7.1	.50
C	3.9	19.5	15	279	6.7	.30	3.9	19.5	15	279	6.7	.30
D	4.4	14.8	17	252	6.3	.31	4.4	14.8	17	252	6.3	.31
E	3.9	10.1	20	254	6.5	.28	4.0	22.8	17	215	6.6	.35

[1] See previous table headings for expression of soil test units

[2] Where A = Nettleton
B = Boyd
C = Robbins
D = Kloster
E = Opio

of the field is designated according to the directions of the fields in relation to NE, NW, SE and SW respectively. The data in the tables show that the individual fields are variable.

Field No. 1 appears more variable in test values for available potassium among samplers. The difference between the highest and lowest values for individual quarters are 197, 121, 170, and 227 for the NE, NW, SE, and SW respectively. Other tests show small magnitudes of variation within the field and among samplers.

Field No. 2 showed higher variability in test values for nitrate-nitrogen than other tests. The pH test values show less variation among samples collected by individuals within fields. The variation in organic matter test results appear irregular (Table 11) among samplers within fields.

Field No. 3 was quite variable in available phosphorus (Table 12) among samplers. However, the field appears to be low in available phosphorus and almost uniformly higher in pH, soluble salts and organic matter. This was a bottom land and was somewhat poorly drained. Perhaps this too may suggest the reason for high values of pH and low values available for phosphorus.

Field No. 4 shows high variations in test results for soluble nitrates, available phosphorus, and available potassium. Organic matter, pH, and soluble salt test values show small variations among samples collected by individual samplers (Table 13).

The overview of the test results presented in Tables 10-13 indicates that the fields and the samplers were variable. While the field variability may be accredited to inherited genetic properties,

the variation due to individual samplers is probably a result of not observing the simple sampling procedures provided.

SUMMARY AND CONCLUSIONS

It was established that a wide variation in soil test results was caused by individual samplers. The largest variations in test values occurred among samplers in the use of Method I for which no instructions were provided prior to sampling. Sampling depths and sampling tools were variable among samplers when taking soil samples by Method I. The technique may in part explain the wider variations in test values on samples collected by the samplers.

Phase II of the sampling experiment was carried out using simple instructions. This resulted in reduced variations in test values among samples collected by individual samplers. It thus shows that by providing the samplers with sampling instructions, variations in soil test results caused by samplers may be reduced.

The samplers had had varied experience in so far as soil fertility and soil sampling were concerned. This was noted in the manner in which the individual samplers used stratified methods (III and V). These variations resulted because of the difference in evaluating the major topographical criteria for stratifying the fields.

The samplers differed widely in the use of directional materials. This suggests that some did not follow the sampling instructions provided.

The specification of fixed sampling depth (15 cm) and fixed number of individual samples was intended to reduce undue variations among samples collected by individuals. It is suggested that some of the variations in the test values might have resulted from samplers

unintentionally mixing soils of dissimilar soil horizons.

It was observed that there were wider variations among samples collected by Method I within fields than among those collected under instructions.

There was no significant difference among all tests, except pH, due to analytical method. This much difference may be attributed to the reading of the instrument by the analyst.

It was found that by use of simple instructions, wide variation among samples collected by individuals could be reduced. This appears to suggest that it is important to keep the samplers properly informed (through instructions) of their duty if they are to collect soil samples that represent soil fertility of a particular field.

In conclusion, it has been found that samplers are different. Method IV showed the least variation in test results among samples collected by individuals. This suggests that when fields are divided into equal parts, and each partition is sampled separately, soil tests are more representative of the soil fertility of the field.

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APPENDIX A

Directions used in collecting soil samples in Phase II of sampling experiment.

I. <u>Soil Sampling Information and Directions</u>

1. Name of farmer cooperator
2. Location of farm:
    a. County
    b. Section
    c. Township
    d. Size of farm
3. Date of sampling
4. Name and address of person sampling
5. Historical information
    a. Soil type
    b. Last year field was fertilized
        (i) Kind of fertilizer used
        (ii) Amount used per hectare
    c. When last the farm was
        (i) Manured
        (ii) Grown legumes, if so what type
    d. Type of crop grown last and yield per hectare

II. <u>Directions and Procedures</u>

1. Sampling method: Simple random sampling
2. Sampling depth: 15 centimeters
3. Number of samples to make a composite sample: 25

4. Examine the field physically and note any peculiar spots.

5. Avoid sampling any unusual spots.

6. Use a stick about 20 centimeters long and about 2 1/2 centimeters in diameter. Mark one end with black ink.

7. Observe the boundary of the field to be sampled, and take a few steps from the side towards the center and flip the stick into the air. Exert enough energy to enable the stick to land around you. Sample the spot where the marked end of the stick faces, right on the very edge. This is the first sample, repeat the process, taking a few steps away from the spot that has just been sampled. Ensure that the tossing of the stick leads you to take representative samples from the field.

8. Take 25 samples and mix them to obtain a composite sample. Ensure that the mixing is thoroughly done. The sample should be carefully handled to avoid contamination. Bring the sample to the Soil Testing Laboratory where it will be air-dried and analyzed.

9. Sketch out the field map on the sheet given and delineate the spots sampled, numbering in the order of sampling.

III. <u>Directions and Procedures</u>

1. Sampling method: Stratified systematic zig-zag method.

2. Sampling depth: 15 centimeters

3. Number of samples: 25 to make one composite sample.

4. Examine the field physically and note any unusual spot, including slopes, topography, drainage system.

5. Avoid sampling any peculiar spot.

6. Before taking any sample, stratify the field according to the nature and types of soil conditions found in the field. Proceed to sample in a zig-zag fashion for the strata created. Take 25 samples along each zig-zag line within each stratum. Mix the sample taken from each stratum to form a composite sample and draw one sample only from each thoroughly mixed lot.

7. The number of stratum in the field will depend on the conditions existing in the field itself. Ensure that the samples are well kept to avoid them getting contaminated. Bring all the samples to the Soil Testing Laboratory where they will be air-dried and analyzed.

8. Sketch out the farm and delineate the spots sampled, following the zig-zag lines, in the order of sampling.

IV. Directions and Procedures

1. Sampling method: Systematic grid method

2. Sampling tool: Soil tube

3. Sampling depth: 15 centimeters

4. Examine the field physically and note any unusual spots, including slopes, topography, drainage problems and soil types.

5. Set out to divide the field into equal parts to grid pattern. Correlate the number of the grid blocks to correspond to the number of soil samples envisaged, i.e. 25.

6. Take 25 samples from within each grid square and make a composite sample by mixing the samples into a bucket to make one sample for each grid area. Ensure that the samples are thoroughly mixed and draw out a subsample from it.

7. Ensure that the sample is properly kept to avoid any contamination.

8. In all, take 25 subsamples from the field.

9. All samples properly labeled should be brought to the Soil Testing Laboratory where they will be air-dried and analyzed.

10. Sketch out the farm and delineate the grid patterns and the areas sampled within the grid-squares.

V. Directions and Procedures

1. Sampling method: Stratified random method

2. Sampling tool: Soil tube

3. Sampling depth: 15 centimeters

4. Examine the field physically and note any unusual spots, including slope, topography, drainage problems, soil types.

5. Set out to divide the field into uniform strata according to the size and nature of the land. This takes into consideration

slopes, soil types, drainage system of the land, and any peculiar spots which otherwise would interfere with the uniformity sought for in the field within each stratum.

6. Sample each stratum separately and take 25 samples from each one of them and mix them to make a composite sample for each stratum. The number of strata to a field will depend on the nature and kinds of soil variability existing in the field.

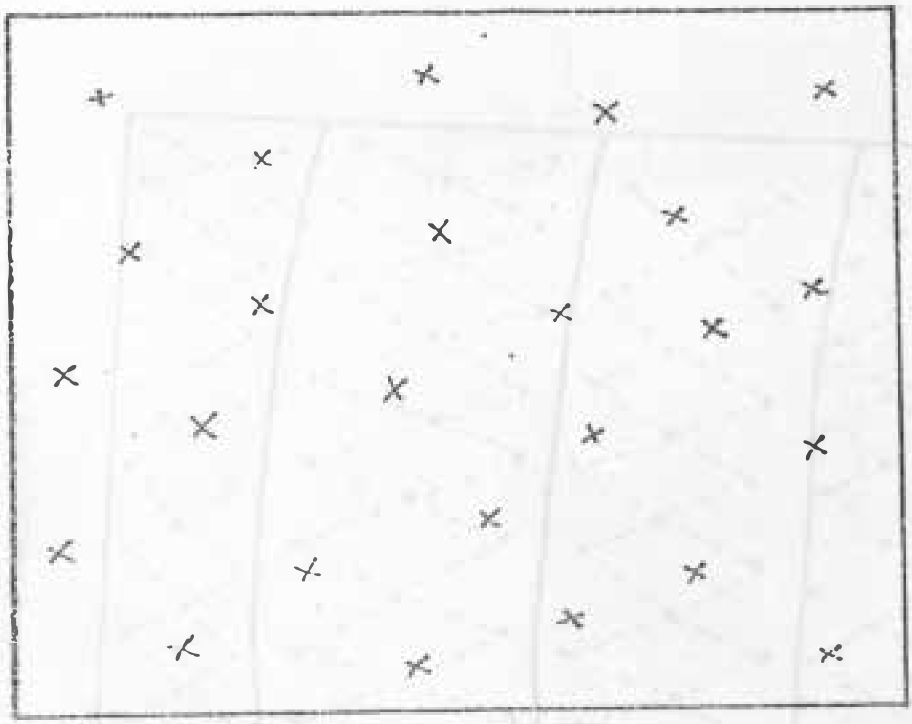
7. The samples taken should be carefully handled to avoid any contamination.

8. All samples properly labeled should be brought to the Soil Testing Laboratory where they will be air-dried and analyzed.

9. Sketch out the farm and delineate the different strata and the areas sampled within each stratum.

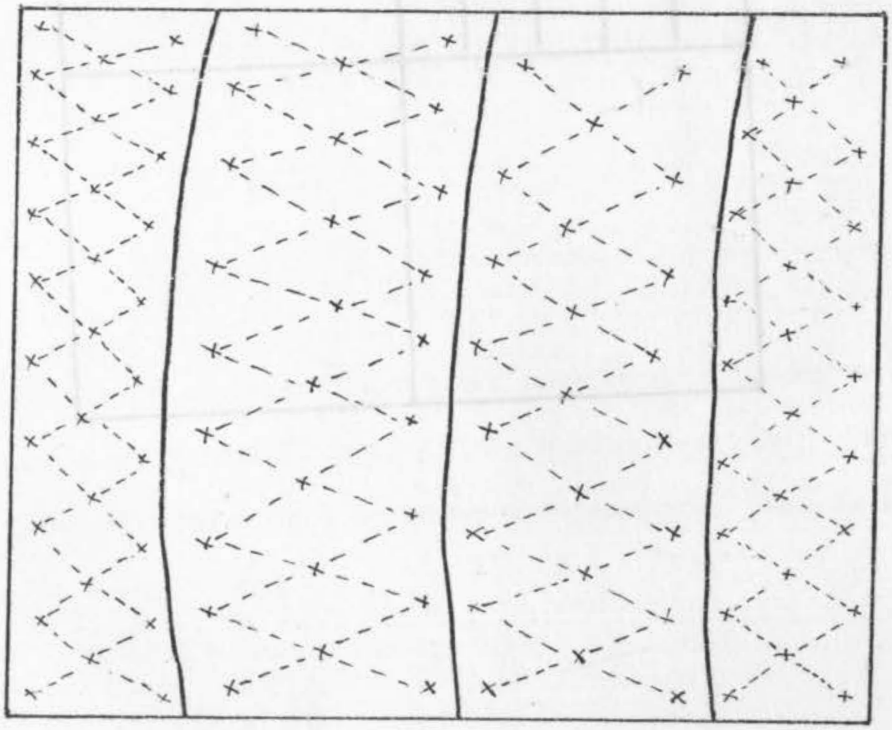
RANDOM SAMPLING METHOD

The following diagram, Figure 1, is an illustration of a random sampling procedure in the field. It is intended to show you what is expected of you in the carrying out of this sampling. Use the 20 centimeter stick marked at one end for locating the site to sample. Flip it into air, it will fall randomly and take soil sample from where the marked end is pointing. Do this 25 times within the field.



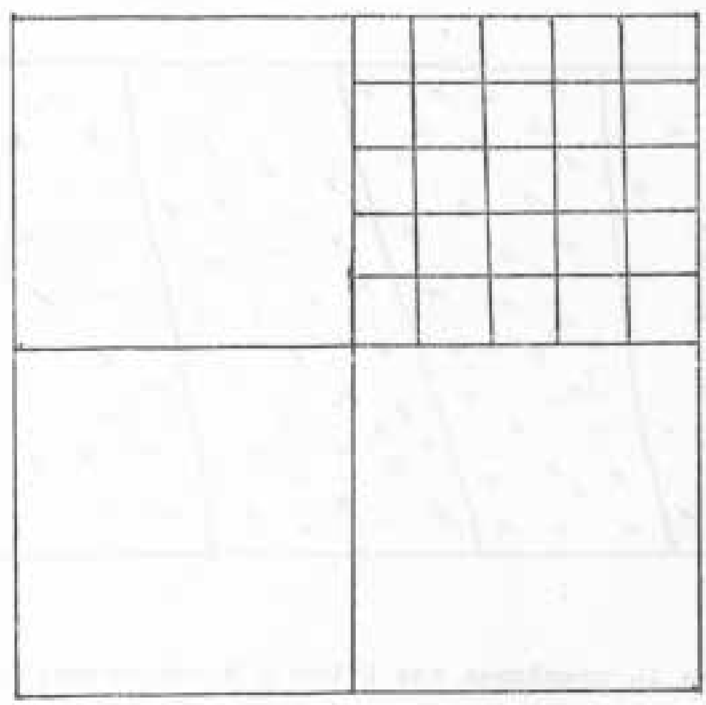
STRATIFIED SYSTEMATIC ZIG-ZAG METHOD

The following diagram, Figure 2, is an illustration of a stratified systematic zig-zag sampling practice in the field. It is intended to show you how to sample the field by this procedure. Remember to divide the field in accordance to different soil conditions (Systematic zig-zag means taking a pre-determined number of steps in between each spot from which you are to take a sample).



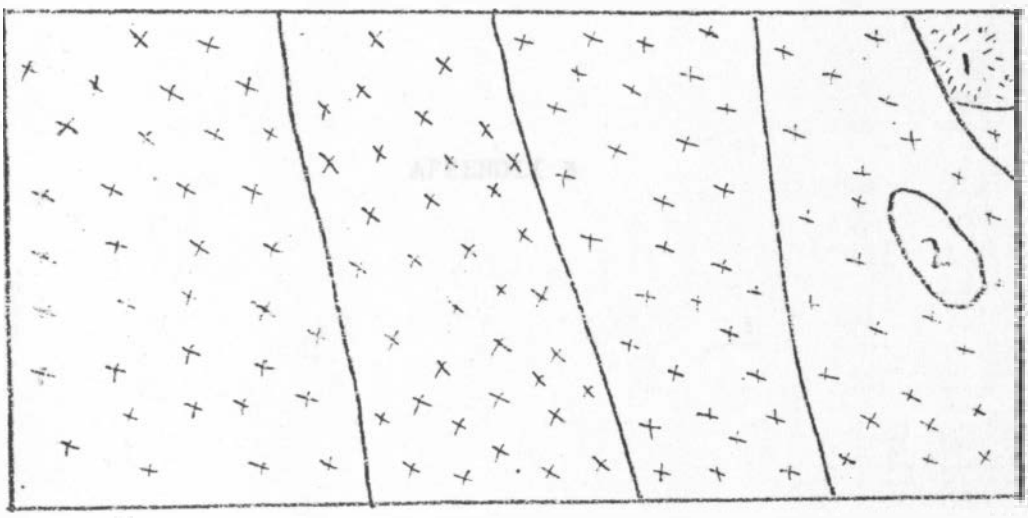
SYSTEMATIC GRID METHOD

The following diagram, Figure 3, is an illustration of a systematic grid sampling practice in the field. It is intended as a guide for you in sampling this field. You are to divide the field in equal grid-square-blocks in accordance to the size of the field and the number of samples to be taken from each quarter of the field.



STRATIFIED RANDOM SAMPLING METHOD

The following diagram, Figure 4, is an illustration of a stratified random sampling practice in the field. The dividing of the field into individual soil conditions depends on variation which exists in the field to be sampled. It is intended to show you what is expected of you, but the numbers, sizes, and the kinds of conditions and shapes will depend on the kinds of landscapes of the field.



(In this diagram spots 1 and 2 are specimens of examples of unusual areas that may be encountered in the field during sampling. Under such situations, the particular spot should not be sampled. One is a rock spot and two is a wet spot.)

APPENDIX B

Table 1. Field 1. Range of chemical analysis results for soil samples collected by individual persons

Sampler	Range	Organic Matter %	Nitrate-Nitrogen ppm N	Available Phosphorus kg of P/ha	Available Potassium kg of K/ha	pH	Soluble Salts mmho/cm
Nettleton	High	4.0	14	30	417	6.8	0.42
	Low	3.5	5	7	232	6.0	0.25
	Mean	3.7	10	15	333	6.4	0.31
Boyd	High	4.1	20	25	435	7.7	0.55
	Low	3.4	9	10	282	6.4	0.23
	Mean	3.8	11	20	361	6.7	0.31
Robbins	High	3.6	18	37	452	7.2	0.59
	Low	3.2	8	7	210	6.4	0.30
	Mean	3.4	15	17	296	6.7	0.40
Kloster	High	3.7	18	22	370	7.4	0.48
	Low	3.0	6	10	183	6.4	0.25
	Mean	3.5	12	12	245	6.8	0.36
Opio	High	4.2	15	64	378	7.4	0.45
	Low	3.6	4	10	170	6.4	0.22
	Mean	3.8	8	22	259	6.7	0.30

Table 2. Field 2. Range of chemical analysis results for soil samples collected by individual persons

Sampler	Range	Organic Matter %	Nitrate-Nitrogen ppm N	Available Phosphorus kg of P/ha	Available Potassium kg of K/ha	pH	Soluble Salts mmho/cm
Nettleton	High	4.6	50	49	575	7.8	0.71
	Low	3.5	23	10	353	6.4	0.36
	Mean	3.9	42	27	427	7.6	0.52
Boyd	High	4.6	49	62	556	7.9	0.72
	Low	3.8	14	20	343	7.2	0.31
	Mean	4.1	28	32	446	7.5	0.49
Robbins	High	4.0	62	32	432	7.9	0.61
	Low	3.4	46	25	269	7.2	0.50
	Mean	3.7	53	27	382	7.6	0.58
Kloster	High	4.1	51	42	464	7.9	0.60
	Low	3.5	35	20	326	7.1	0.28
	Mean	4.0	41	30	370	7.5	0.52
Opio	High	4.4	61	37	464	7.8	0.63
	Low	3.9	40	25	380	7.2	0.40
	Mean	4.2	49	30	427	7.4	0.54

Table 3. Field 3. Range of chemical analysis results for soil samples collected by individual persons

Sampler	Range	Organic Matter %	Nitrate-Nitrogen ppm N	Available Phosphorus kg of P/ha	Available Potassium kg of K/ha	pH	Soluble Salts mmho/cm
Nettleton	High	5.6	13	12	388	8.1	1.45
	Low	4.1	1	5	267	7.8	0.25
	Mean	4.8	5	7	306	8.0	0.64
Boyd	High	5.8	21	22	366	8.2	1.05
	Low	4.5	8	10	267	7.9	0.23
	Mean	5.1	15	12	304	8.1	0.57
Robbins	High	4.9	12	17	326	8.1	0.98
	Low	4.2	6	5	208	8.0	0.35
	Mean	4.7	10	10	287	8.0	0.62
Kloster	High	6.0	20	17	321	8.8	0.88
	Low	4.6	5	10	227	7.8	0.35
	Mean	5.2	9	5	279	8.0	0.63
Opie	High	4.9	23	10	366	8.1	0.80
	Low	3.9	7	10	203	7.8	0.59
	Mean	4.5	14	10	301	8.0	0.69

Table 4. Field 4. Range of chemical analysis results for soil samples collected by individual persons

Sampler	Range	Organic Matter %	Nitrate-Nitrogen ppm N	Available Phosphorus kg of P/ha	Available Potassium kg of K/ha	pH	Soluble Salts mmho/cm
Nettleton	High	5.4	13	25	425	6.7	0.40
	Low	3.2	1	12	240	6.0	0.25
	Mean	4.0	6	17	269	6.4	0.32
Boyd	High	5.4	17	27	366	7.1	0.40
	Low	3.8	5	15	217	6.5	0.23
	Mean	4.5	11	22	319	6.7	0.33
Robbins	High	4.1	26	17	294	7.2	0.45
	Low	3.5	9	15	227	6.3	0.31
	Mean	3.9	19	17	249	6.6	0.35
Kloster	High	4.8	19	20	432	6.6	0.40
	Low	3.4	1	10	190	6.2	0.28
	Mean	4.0	11	15	242	6.4	0.33
Opio	High	5.0	26	22	370	7.8	0.40
	Low	3.6	10	15	173	6.0	0.28
	Mean	4.0	18	20	259	6.4	0.33

APPENDIX C

Figure 1. Field 1. Duane Colburn. Variations in Field Stratification Among Samplers

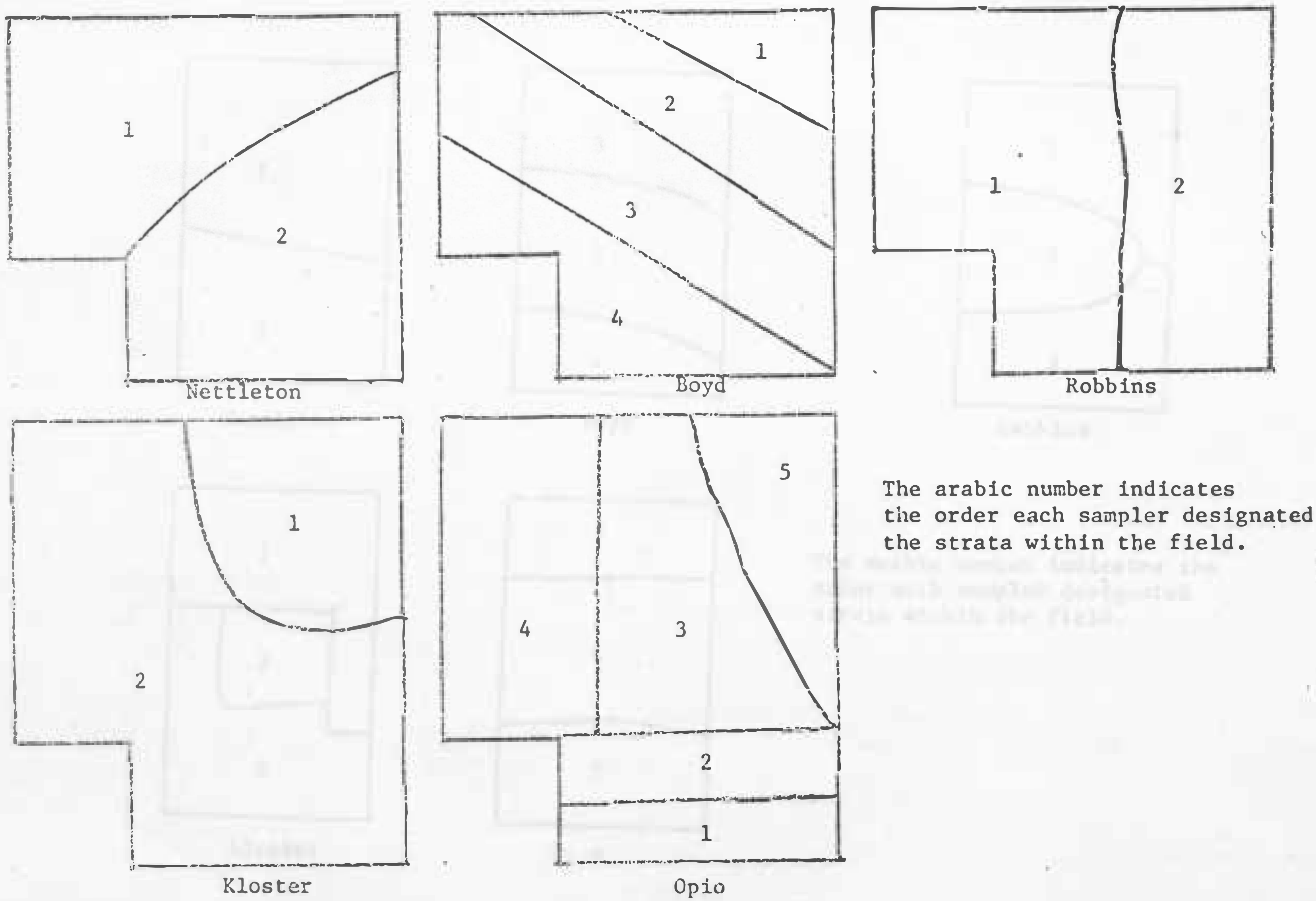
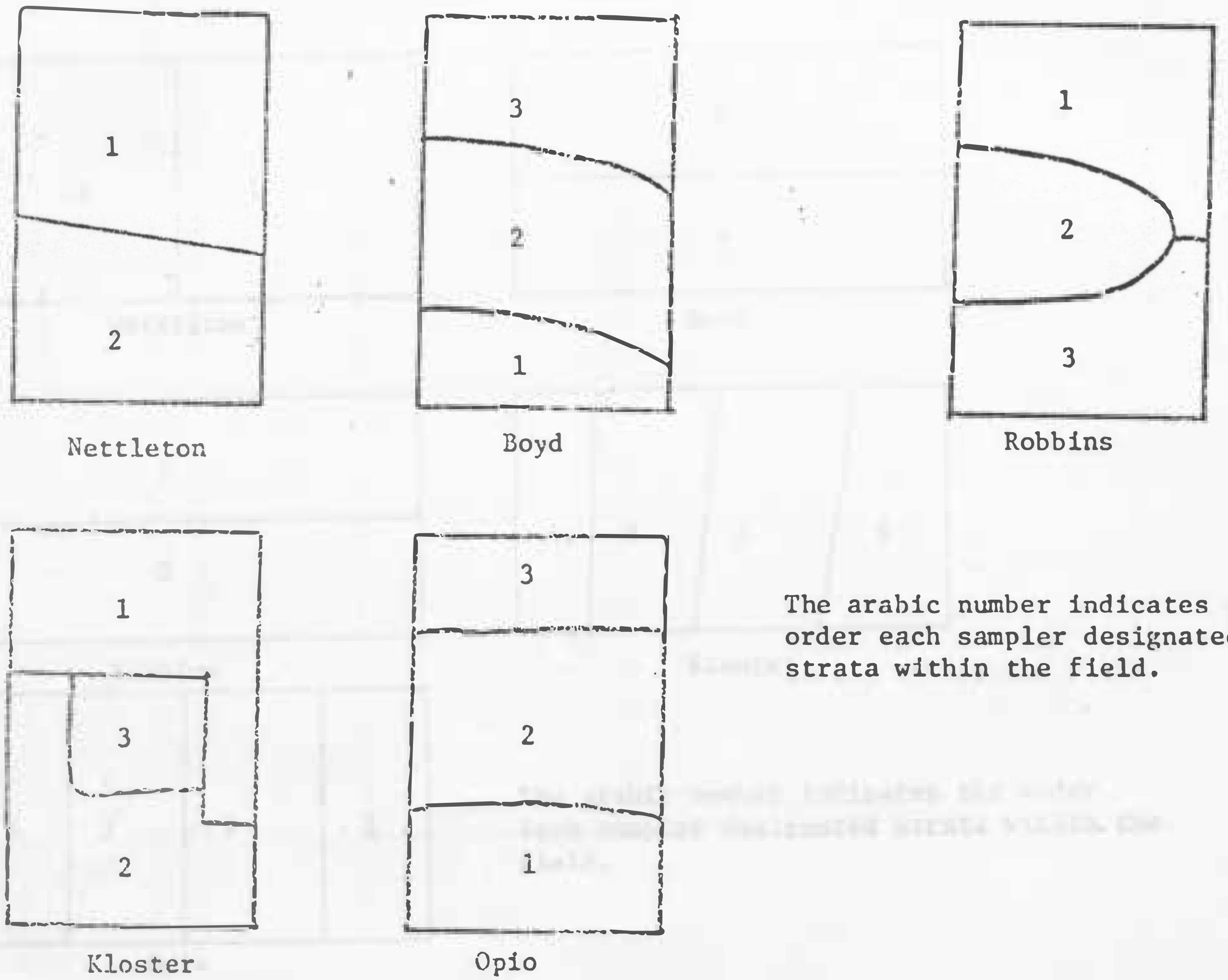
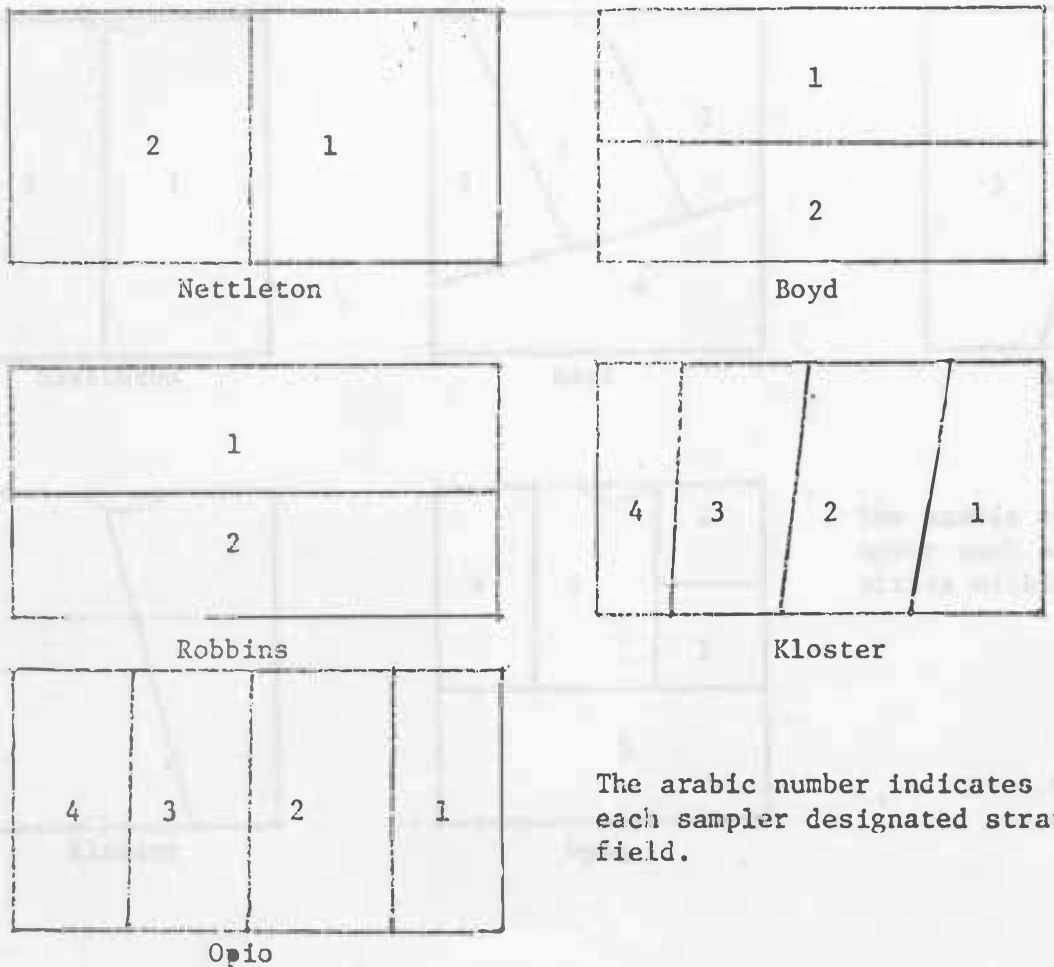


Figure 2. Field 2. Cecil Hall. Variations in field stratification among samplers



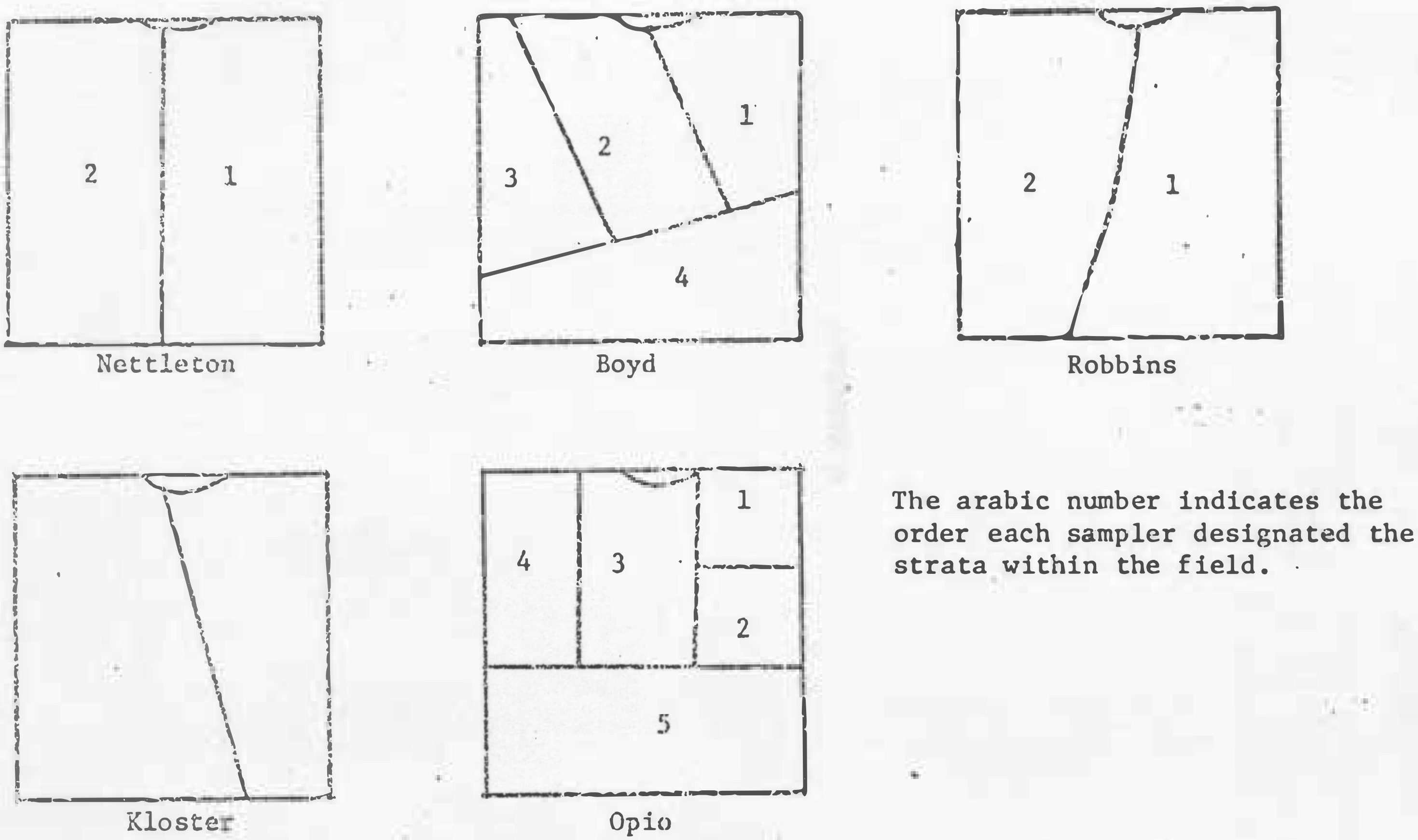
The arabic number indicates the order each sampler designated strata within the field.

Figure 3. Field 3. Royce Emerick. Variations in Field Stratification Among Samplers



The arabic number indicates the order each sampler designated strata within the field.

Figure 4. Field 4. Lyle Strassberg. Variations in field stratification among samplers



APPENDIX D

Table 1. Mean test results showing variations among soil samples collected by different methods and samplers

Method	Sampler	Organic Matter %	Nitrate-Nitrogen ppm N	Available Phosphorus kg of P/ha	Available Potassium kg of K/ha	pH	Soluble Salts mmho/cm
1	Nettleton	4.2	14	17	351	6.9	0.40
	Boyd	4.4	20	15	257	7.1	0.58
	Robbins	3.8	17	15	245	7.2	0.47
	Kloster	4.2	13	15	363	7.2	0.47
	Opio	4.1	20	17	316	7.2	0.46
2	Nettleton	4.2	18	12	319	7.2	0.50
	Boyd	4.1	19	25	343	7.5	0.36
	Robbins	4.0	23	20	319	7.3	0.56
	Kloster	4.1	17	12	254	7.0	0.48
	Opio	4.1	20	17	316	7.2	0.46
3	Nettleton	4.0	18	17	309	7.2	0.45
	Boyd	4.5	14	20	375	7.3	0.41
	Robbins	4.0	27	17	311	7.3	0.45
	Kloster	4.2	20	17	279	7.2	0.43
	Opio	4.1	22	17	331	7.1	0.46
4	Nettleton	4.1	18	15	321	7.2	0.53
	Boyd	4.4	15	20	366	7.3	0.44
	Robbins	3.9	26	17	316	7.2	0.48
	Kloster	4.4	19	17	282	7.1	0.44
	Opio	4.1	23	20	311	7.1	0.48
5	Nettleton	4.0	17	17	329	7.2	0.44
	Boyd	4.4	16	22	363	7.3	0.40
	Robbins	3.9	24	17	309	7.2	0.49
	Kloster	4.0	19	15	274	7.2	0.52
	Opio	4.1	22	17	329	7.1	0.46