REPRODUCIBILITY OF SOIL TEST VALUES OBTAINED BY DIFFERENT FIELD SAMPLING TECHNIQUES[1/]

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ABSTRACT

Single-core soil samples were taken on a grid-pattern in nine fields in southern Idaho. Soil tests for sodium bicarbonate-soluble P and K, and DTPA-extractable Zn indicated wide variability of these elements in most fields. Analyses of composite samples taken from the same areas by two other persons and the single-core averages for each field agreed closely. The single-core average values and the values obtained from composite samples, while highly reproducible, were not reliable indicators for predicting fertilizer needs of the fields because areas testing low within the fields were not delineated. An initial intensive sampling, in which single-core samples are taken on a grid pattern and analyzed separately, is needed to determine the fertility variability of a field. Once the variability is established, areas may be selected to monitor soil test changes with time and cropping.

INTRODUCTION

Soil testing is widely used to determine fertilizer needs. Many thousands of samples are analyzed for several elements each year by state and private laboratories. Chemical procedures have been developed for determining indexes related to the nutritional status of various crops grown on different soils. Some of these methods use sophisticated techniques and instruments that allow rapid and routine determinations of several different elements. Unless the samples analyzed represent the fertility status of the field, however, extreme refinement of chemical procedures and determinations is of little value. Indeed, information derived from nonrepresentative samples may be misleading and result in excessive fertilizer costs, or less than maximum crop yield or quality.

The relationships between soil tests and crop growth and yield are developed on small areas having uniform soil test levels for the element under study. Results from several experimental sites having a range of uniform soil test levels are needed to determine a critical level. Thus, use of soil tests for diagnosis and prediction assumes that the sample to be analyzed came from an area having a uniform soil nutrient level, and that the sample analyzed represents the conditions prevailing throughout the field. The difficulty in obtaining a reliable composite soil sample becomes obvious from Table 1. For example, sampling a 20-acre field by taking 3/4-inch cores requires that 280 be taken to equal 1 ppm of the soil; 28 cores equal only 0.1 ppm of the soil. Rarely is sampling more intensive.

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Table 1. The number of samples possible in an acre when sampled with different sampling tools.

Sample dimensions in	Sample area in^2	Samples/acre in millions
Cores		
0.75	0.442	14.19
1.0	0.785	7.99
1.5	1.767	3.55
Shovel slice		
2 × 4	8	0.78

1 acre = 43560 ft^2 = 6,272,640 in^2

A sample usually becomes more representative of a field by taking a larger fraction of the soil volume in the sample, i.e., as more or larger cores are taken. Many composite samples, however, are not representative because of the nonuniformity of the nutrient level within the field. When cores are composited from areas that range from high to low in the element of interest, the soil test results reflect an average of all cores taken. Such an average may be meaningless, or may reflect conditions over only a small part of the field. The importance of good sampling cannot be overemphasized for the simple reason that good results, and hence, good fertilizer recommendations, cannot be made based on values of nonrepresentative samples.

Soil testing results are subject to three main sources of variation: laboratory, seasonal, and field. Of these, field variation is the only one considered here; our experience and that of others (Cameron, et al., 1971; James and Dow, 1972) indicate that errors associated with chemical methods in a well run competent laboratory are minor compared to field sample variation, and since the samples taken for this study were all taken at one time, we are not concerned with seasonal variation.

Our objectives in this study were (a) to determine if reproducible soil test values could be obtained by different samplers, and (b) to determine the variability in nutrient levels among samples from fields that appeared uniform.

METHODS

Sampling Procedure and Sample Preparation

Nine fields ranging in size from 4 to 15 acres were sampled in southern Idaho during late March 1978. A grid pattern was established in each field, and single cores were taken at 100- to 150-foot intervals. From 20 to 27 cores were taken, depending on field size. Composite samples of 10 and 20 cores each were taken from within the grid by two other persons. These samples were taken according to the sampler's own ideas as to the best way to sample each area. All cores were 3/4 inch in diameter and taken to a depth of 12 inches.

The samples were dried rapidly in a forced draft drying chamber at 50° C and crushed to pass a 2-mm stainless steel sieve. The grinder was made of stainless steel and was designed to avoid crushing primary particles.

Chemical Determinations

The samples were analyzed for sodium bicarbonate-soluble P and K (Olsen, et al., 1954), and for DTPA-extractable Zn (Lindsay and Norvell, 1969).

RESULTS

The soil test results for the single-core samples, along with statistical evaluation for each field, are given in Table 2. The fields were highly variable for all elements tested as indicated by the ranges, the coefficients of variation (CV), and the confidence limits (L_{95}). All of the fields had been fertilized with Zn and K. Topsoil removal by erosion or cutting and filling in land leveling was probably the major factor contributing to the variation. The distribution of the single-core soil test levels is shown in Table 3. Critical levels of 10, 100, and 0.6 ppm were used for P, K, and Zn, respectively. Cores from four of the fields had P levels lower than 10 ppm. One field had K values lower than 100 ppm, and two fields had Zn values less than 0.6 ppm. Single-cores for two fields (E, F) showed soil tests lower than the critical levels for more than one element. Field E had single-core soil tests that were low in P and K, but they were usually not for the same cores. Most cores in field F were low in P and Zn.

The mean values for the single-core samples are compared with the values for the 10- and 20-core composite samples in Table 4. If one assumes that the means of the single-core samples represent the field average, the composite samples estimated the average for the field reasonably well, although there were some discrepancies. Even the 10-core composite samples gave values that were surprisingly close to the single-core means. Only two high P values (fields D and F), and two high Zn values (field I) differing from the single-core means by more than the 95 percent confidence interval (L_{95}) are shown for the 10-core composite samples. All K values were within these limits. The confidence limits computed from the single-core values indicate that a composite sample taken similarly would give a soil test value within $\pm L_{95}$ of the field mean 95 percent of the time. The 20-core composite samples gave values within $\pm L_{95}$ for P and K on all fields, but were somewhat less reliable for Zn. Although values for samples taken by different samplers differed somewhat, no consistent trend was evident for any of the elements determined. None of the differences between samplers noted were significant at the 5 percent probability level.

In Table 5, fertilizer recommendations based on the single-core samples and the composite samples are compared. The single-core samples indicated fertilization was needed when any single-core value for that element was below the critical level, even though it represented only a small area. Results of the composite samples agreed closely with the means of the single-core samples for P. They failed, however, to predict small areas needing P and K in field E, and Zn in field G. Based on the single-core values, only one-tenth of field E required K, but 30 percent of field G required Zn.

Using the variances for the single-core samples, and the formula $n = t^2_a s^2/D^2$ given by James and Dow (1972), the number of cores required in

Table 2. Soil test mean and variations in nine southern Idaho fields sampled by single cores on a grid pattern.

Field	Size	Nutrient	Single core mean	Range	Coef. of variation	n[1/]	L_{95}[2/]
	acres		ppm	ppm	%		ppm
A	7	P	9.1	3.4- 16.6	48	21	4.2
		K	159	120 -182	11	3	16
		Zn	1.48	0.7- 2.4	34	28	0.48
B	7	P	18.0	10.5- 23.8	21	16	3.6
		K	183	135 -246	18	11	31
		Zn	1.79	1.3- 2.3	5	9	0.27
C	4	P	18.2	13.0- 26.6	18	11	3.1
		K	144	113 -197	14	4	19
		Zn	2.14	1.3- 2.8	21	22	0.43
D	15	P	12.8	6.3- 18.3	26	11	2.7
		K	149	115 -224	19	8	23
		Zn	1.21	0.7- 2.1	30	14	0.30
E	7	P	18.3	6.6- 27.1	28	30	5.1
		K	136	87 -220	22	10	29
		Zn	1.09	0.7- 1.6	26	9	0.28
F	5	P	7.8	2.3- 20.4	39	10	2.9
		K	295	200 -465	21	44	60
		Zn	0.56	0.26- 1.7	62	13	0.33
G	10	P	32.4	14.4- 55.6	32	116	10.1
		K	213	131 -300	26	33	53
		Zn	0.76	0.46- 1.44	37	9	0.29
H	5	P	35.2	15.8- 49.9	28	109	9.8
		K	152	104 -235	21	11	30
		Zn	1.49	0.9- 2.3	26	16	0.37
I	5	P	22.6	16.8- 32.2	16	15	3.5
		K	173	112 -231	18	11	30
		Zn	1.04	0.6- 1.5	25	8	0.25

1/ n equals the number of cores required in future samplings for the values to lie within 2, 20, or 0.2 ppm of the mean for P, K, or Zn, respectively.

2/ L_{95} = 95 percent confidence interval.

Table 3. Distribution of single-core samples according to soil test for nine fields.

Soil test level	No. cores in fields having various soil test levels								
	A	B	C	D	E	F	G	H	I
ppm									
P									
< 5	3	0	0	0	0	4	0	0	0
5-10	11	0	0	6	1	12	0	0	0
10-15	3	4	3	11	3	5	1	0	0
> 15	4	17	18	10	16	0	19	21	21
K									
< 100	0	0	0	0	2	0	0	0	0
100-125	2	0	3	4	6	0	0	2	1
125-150	3	3	11	12	7	0	5	10	2
> 150	16	18	7	11	5	21	15	9	18
Zn									
< 0.6	0	0	0	0	0	16	6	0	0
0.6-1.0	4	0	0	8	9	3	9	9	11
> 1.0	17	21	21	19	11	2	5	12	10

Table 4. Soil test values for composite samples and the average single-core values for samples taken from nine fields by different samplers.

Sample description	Field soil test values								
	A	B	C	D	E	F	G	H	I
	ppm								
P									
Single-core mean	9.1	18.0	18.2	12.8	18.3	7.8	32.4	36.9	22.6
10-core composite									
A	12.5	16.0	19.7	12.5	14.2	14.1	33.4	37.1	23.4
B	9.6	17.0	18.8	15.6	16.0	8.1	36.5	39.1	25.3
20-core composite									
A	10.8	15.6	17.3	11.8	17.9	8.1	32.9	34.6	23.1
B	9.6	18.1	18.7	14.0	16.5	8.4	34.6	41.6	23.5
K									
Single-core mean	159	183	144	149	136	295	213	153	173
10-core composite									
A	162	158	144	167	133	286	192	145	155
B	160	174	145	162	154	258	232	175	157
20-core composite									
A	157	161	136	149	136	280	209	141	152
B	162	178	138	156	140	262	218	182	148
Zn									
Single-core mean	1.48	1.79	2.14	1.21	1.09	0.56	0.95	1.49	1.04
10-core composite									
A	1.35	1.67	1.92	1.08	0.88	0.35	0.80	1.74	1.57
B	1.69	1.75	2.10	1.19	1.10	0.63	0.94	1.84	1.33
20-core composite									
A	1.48	1.51	2.11	0.86	0.93	0.51	0.70	1.45	1.89
B	1.69	1.72	2.00	0.86	1.19	0.58	0.85	1.94	1.09

Table 5. Fertilizer recommendation for P, K, and Zn based on different soil samples taken from nine fields in southern Idaho.

Soil samples[1/]	Fertilization as indicated from different soil samples								
	Field sampled								
	A	B	C	D	E	F	G	H	I
Single cores	P	-	-	P	P, K	P, Zn	Zn	-	-
Single-core mean	P	-	-	-	-	P, Zn	-	-	-
Composite samples									
A_{10}	-	-	-	-	-	Zn	-	-	-
A_{20}	-	-	-	-	-	P, Zn	-	-	-
B_{10}	P	-	-	-	-	P	-	-	-
B_{20}	P	-	-	-	-	P, Zn	-	-	-

1/ Single cores: Chemical symbol indicates soil test for at least one core was below critical level.

Single-core mean: Chemical symbol indicates average soil test was below critical level.

Composite samples: Chemical symbol indicates soil test on 10- or 20-core samples taken by samplers A and B were below critical level.

future samplings to obtain soil tests that lie within prescribed limits of the initial mean value can be calculated. In the formula, n is the number of cores, t_a is student's "t" value, s^2 is the variance calculated for the initial sampling, and D is the maximum difference desired between the soil tests for the initial and subsequent samplings. We used "t" at the 5 percent probability level. Thus, n is the number of cores required in repetitive samplings to obtain soil test values within the prescribed limits 95 percent of the time. The concept of the formula was tested using the soil test values for the composite samples. As shown in Table 2, n is the number of cores needed for the soil tests for P, K, and Zn where the prescribed limits for D are 2, 20, and 0.2 ppm for P, K, and Zn, respectively. Of the nine fields sampled, 20 cores per field adequately reflected the field mean within the prescribed limits except for P on fields A, E, G, and H; K on fields F and G; and Zn on fields A and C. Field D was the largest field sampled (15 acres); yet, based on the grid sampling, a composite of 20 cores adequately reflected the field mean for all three elements.

DISCUSSION

The data reported here are similar to those presented by Cameron, et al. (1971), James and Dow (1972), and Painter, et al. (1969). Variability within most fields was much greater than expected, especially where land leveling had been extensive. The results of the study indicate clearly that composite soil test values are reproducible, even with the samples taken by different persons.

It is surprising that relatively few cores, taken in a somewhat random fashion or on a grid pattern from highly variable fields, yield soil samples that give reproducible soil test values. Cameron, et al. (1971) showed that the number of cores required to adequately measure the field mean did not increase drastically with field size. They sampled one 99-acre field taking 1040 single cores on a grid pattern and found the variation was no greater than on 20- to 30-acre fields. It seems that the main requirement for obtaining reproducible composite samples from variable fields is to make sure that the sample contains cores that represent all kinds of variation in the field and in proportion to the areas involved.

Despite the reproducibility of tests run on composite samples from the same field, the major problem is that of using the test results to predict fertilizer needs. The soil variability in a field may vary so widely that an average soil test determined from a composite sample will not adequately indicate the fertility conditions. The P results for field D shown in Table 3 illustrate this point very well. The single-core mean for this field was 12.8 ppm P and the 20-core composites averaged 12.9 ppm P. All of these values are above the critical level, thus indicating P fertilization was not needed. The single-core average as shown in Table 4, however, was made up of 6 values below 10 ppm P, 11 ranging from 10 to 15 ppm, and 10 greater than 15 ppm. The low values were not scattered at random, but occurred together near the center of the field. Such fertility patterns are common (James and Dow, 1972). If the variability in this field were not known, and no P fertilizer was applied, as indicated by the test on the composite samples, crops grown on 22 percent of the field would likely yield less than maximum. If, on the other hand, the field were known to be variable, but low P areas were not defined and it was arbitrarily decided to apply P uniformly to take care of the low P spots, most crops grown on 75 percent of the field would not have benefited from the added P. If such a decision as this were made, then why soil test?

Fields B, C, H, and I also showed a great deal of variability for the three elements (Tables 2 and 3). Nothing practical can be done about the variability in these fields because all values for all elements determined are high. Determining the variability of fields such as this might not improve the present year's fertilization practices, but the information could be used in the future. Dow (1974) proposed a method for taking into account the fertility variability in fields by first sampling the field on a grid pattern and then, on the basis of the fertility pattern, establishing monitoring sites whereby soil test levels could be followed in subsequent years without having to repeat the intensive sampling of the entire field. If areas that test low can be fertilized separately or given different rates, eventually uniformity can be attained. Such a soil testing scheme requires taking and analyzing a great many samples for the initial sampling. If such a scheme were adopted, soil testing fees would have to be adjusted to make it economically feasible for growers and laboratories. Dow and James (1973) have indicated such a fee schedule for Washington State University.

SUMMARY

Soil test values for P, K, and Zn were determined on samples taken from nine fields in southern Idaho. The fields ranged from 4 to 15 acres in size. They were sampled at the same time by three people. One took single-core samples on a grid pattern of 100 to 150 feet between samples; two others took composite samples from the same area. The results indicate that for

each field the average soil test values for the single-core samples and the values for the composite samples generally agreed closely, but that because of fertility variability in the fields, composite samples and single-core averages were not reliable for predicting fertilizer needs, except in some fields that tested high for all three elements.

The values for the single-core samples showed that fertility varied widely within all fields sampled. Similar nonuniformity probably exists in most fields of the area. Only by intensive sampling procedures can low or high fertility areas in fields be determined and fertilized separately. Once the variability pattern is determined, sampling sites can be selected for monitoring soil nutrient levels and determining fertilizer needs for future crops.

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