SAMPLING SOIL PLOTS

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Methods of sampling the soil of fertility plots for investigation as to its chemical content are by no means standardized. One is often led to question the conclusions drawn by investigators from their analytical results when the method of choosing the samples was not indicated or, when given, showed a lack of appreciation of the necessity of accuracy in their selection.

The Official Methods of the Association of Agricultural Chemists (4) leave much to be desired in specific suggestions concerning this matter. The directions specify the taking of a "composite sample" with no statement as to the number or location of the individual parts of the composite.

Wiley (10) reviews the methods employed by the more prominent agricultural experiment stations of Europe. In most cases holes are dug with a spade and the sample is secured by making a composite from slices taken from the sides of these holes. The location or number of these holes is not specified.

Warington (8) points out the difficulties involved in sampling the same plot after some years due to the fact that the quantity of organic matter may be changed and the same volume of soil may not represent the same weight of inorganic matter as was contained in the original sample. He also notes that samples should be chosen for comparison when they are in the same condition, i.e., following the same crop and treatment as to cultivation, and suggests securing the sample after a crop has been harvested and before plowing. Warington gives the method adopted by the Rothamsted station and followed since 1865. In this method a square frame of sheet-iron covering an area of 144 square inches is driven into the soil to a depth of 9 inches and the soil contained within this area constitutes the sample.

Many of the methods given are intended for soil survey purposes. The method employed by the United States Bureau of Soils is given by Whitney (9). Hopkins (2) adopted the very definite plan of taking samples to uniform depths but gives no specifications as to distribution of borings in selecting a composite. It is probably not the intention of any of those engaged in soil survey to return to the identical areas from which the samples were chosen, to collect a second sample at some future date for purposes of comparison. Nevertheless, there are on record numerous cases in which conclusions have been drawn from samples chosen at different dates from approximately the same

area, in which no more adequate precautions were taken than those indicated above for insuring that they actually represented the areas in question.

Unless it is possible to sample a given area of soil as many times as may be desired on the same day with the result that the samples are practically identical in composition, there is no reason to believe that conclusions drawn from a comparison of analyses of samples chosen from the same areas at periods several years apart will be trustworthy. This is particularly true if the work is done by different men whose ideas as to how to sample a plot of ground differ.

Leather (3) chose duplicate samples made up of a composite, of 12 borings each, to a depth of 9 inches from areas on three Indian experiment stations. Determinations of the content of nitrogen, phosphoric acid and potash were made. The laboratory error was least on the nitrogen. The duplicate samples varied from 0.001 to 0.015 per cent of this element, with an average variation of 0.006 per cent.

Thiel (7) selected an area of 200 square meters of uniform soil in which, after the soil had been spaded to plow depth, 10 stakes were driven as locations for sampling. A spadeful of soil was selected from near each stake. The composite sample was then passed through a 2-mm. sieve, thoroughly mixed and dried. These operations were repeated twice each month for a year. Five determinations were made on each composite with fairly concordant results. The nitrogen content of the bimonthly composites, calculated to a depth of 50 cm., varied from 9,090 to 10,269 kgm. per hektare.

Pfeiffer and Blanck (5) chose five samples of soil from each of 6 plots located on an area of 9 square meters of land. Four holes were dug on each plot to a depth of 25 cm., and a slice was taken from the side of each hole for the composite. Determinations were made of the nitrogen in the composites. In no case did the nitrogen in any composite vary from the mean of the 5 composites of that plot by more than 0.0063 per cent.

Robinson and Lloyd (6) determined the experimental error in sampling soil in two fields, one of which was quite uniform in texture and the other was not. We will confine the discussion to the uniform field. No records are given as to depth of sampling or type of auger used. Fifteen borings were made at equi-distant points from an area of $\frac{3}{4}$ acre. Each boring was analyzed separately for its content of phosphoric acid. Assuming that the weight of each boring was the same, one can make certain calculations as to what the percentage of phosphoric acid would have been with any combination of samples of a composite. The results of these calculations show that the composite made up of the entire 15 borings would have contained 0.219 per cent of phosphoric acid. By selecting other composites of 5, 6, 7, 9 and 11 borings chosen according to regular schemes over the area, the percentage of phosphoric acid reported might have varied from 0.212 to 0.229. The analytic error is shown in this investigation, however, to be greater than the sampling error.

Bear and Salter (1) chose 6 composites, each consisting of 38 borings, to a depth of $6\frac{2}{3}$ inches, from a plot of $\frac{1}{10}$ acre. These borings were distributed at regular intervals over the plot. The soil was passed through a 2-mm. sieve and then pulverized to pass a 100-mesh sieve. Each composite was analyzed for total carbon, nitrogen and phosphorus. Five of the six composites were quite uniform in their content of these three elements. The greater variation in the total carbon was 0.07 per cent, in total nitrogen 0.009 per cent, and in total phosphorus 0.002 per cent. In the sixth composite the content of these three elements was higher than the lowest of the five other composites by 0.15 per cent of carbon, 0.018 per cent of nitrogen and 0.004 per cent of phosphorus. The greatest variation in duplicates of any composite was 0.02 per cent of carbon, 0.001 per cent of nitrogen and 0.001 per cent of phosphorus.

OBJECT OF THIS EXPERIMENT

It seems desirable to have some very definite plan of selecting soil samples from fertility plots if analytical comparisons are to be made from time to time of the effect of the fertilizer or other treatments the plots receive. It is logical to decide on the method to be employed before field work is begun in order that samples of the original soil may be selected and set aside under appropriate conditions for comparison with samples to be chosen subsequently from the same plot.

The first question which it was thought best to investigate was that of determining how to choose a composite which would accurately represent a plot for the particular day on which it was chosen. No consideration therefore, was given to the question of the relationship of this sample to one which might be chosen from the same area 10 to 20 years hence.

PLAN OF THIS EXPERIMENT

Two plots of ground each $\frac{1}{10}$ acre in size (21 ft. by 103.7 ft.) were set aside for this test. Plot I was as uniform as could be secured on the experimental field. Plot II was chosen for its lack of uniformity. Stakes were driven at various points in the plots and strings were stretched from stake to stake. At points of intersection samples were chosen. This located the samples at the 45 points indicated in figure 1. The samples were chosen with a $1\frac{1}{4}$ -inch auger. The surface samples represented a depth of $6\frac{2}{3}$ inches and the sub-surface from $6\frac{2}{3}$ to $13\frac{1}{3}$ inches. Care was taken to have the soil at a moisture content which would permit of removing the auger from the hole without losing any of the core. In this latitude the best time for sampling is usually in the month of November. Surface material, leaves and grass were carefully removed before sampling was begun. Both depths were secured by sinking the auger to the proper depth before removing it with the core. If any surface material chanced to fall into the hole before the selection of the second depth,

this material was carefully removed with the auger before taking the sub-surface sample. Each boring was placed in a separate container, taken to the laboratory and placed in the drying room. Twenty days later both plots were sampled again in the same manner and within an inch of the same points, the original stakes having never been removed.

Each sample was weighed and prepared for analysis by discarding all material which would not pass a 10-mesh sieve and pulverizing the remainder in a planetary mill to pass a 100-mesh sieve. The weight of the discard was recorded. Nitrogen determinations in 10-gm. duplicates were made of each air-dry sample, making a total for the two samplings of 720 determinations. If the duplicates did not check within 0.1 cc. of $\frac{1}{4} N$ alkali they were both discarded and another set was run. This was necessary in only a relatively few cases—the analyst, Mr. J. R. Royston, whose services are acknowledged and appreciated, having had considerable experience in nitrogen determinations in soils.

TABLE 1
Arrangement of borings for composites

COMPOSITE	BORINGS
1	1 to 45, inclusive
2	1, 3, 5, 7, 11, 13, 17, 20, 22, 24, 26, 30, 32, 36, 38, 42, 44
3	2, 4, 8, 10, 14, 16, 20, 22, 24, 26, 29, 33, 35, 39, 41, 43, 45
4	1, 2, 3, 4, 5, 19, 20, 21, 22, 23, 24, 25, 26, 27, 41, 42, 43, 44, 45
5	6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40
6	1, 2, 3, 4, 5, 6, 9, 12, 15, 18, 19, 21, 23, 25, 27, 28, 31, 34, 37, 40, 41, 42, 43, 44, 45
7	1, 2, 3, 4, 5, 19, 21, 23, 25, 27, 41, 42, 43, 44, 45
8	1, 2, 3, 4, 5, 20, 22, 24, 25, 26, 41, 42, 43, 44, 45

Plot I was not as uniform in composition as had been anticipated. In the first sampling the nitrogen content of the borings varied from 0.155 to 0.258 per cent in the surface soil and from 0.118 to 0.243 per cent in the sub-surface soil. The nitrogen percentages varied in the second sampling in much the same way, but the highest and the lowest nitrogen content were not always found at the same locations on the plot. In the non-uniform plot the nitrogen content of the individual borings fluctuated from 0.113 to 0.226 per cent and that of the sub-surface from 0.087 to 0.236 per cent, with similar variations in the second sampling. Since individual determinations of both weight of sample and nitrogen content were made, it was possible to calculate what the reported analysis would have been if any given combination of borings had been mixed for a composite sample before analyses were made. The quantity of soil in a boring varied considerably. In the first sampling of plot I the largest core contained 248 gm. and the smallest 116 gm.

Arranging the single borings into eight groups as shown in table 1 according to what might be considered fairly logical schemes of sampling, it was found

that the analyses which would have been reported for any plot on the basis of these composites varied considerably both with the method of choosing the samples for the composite and the number of samples entering into the composite. Table 2 shows the results of this grouping of samples.

TABLE 2
Nitrogen in composites

	COMPOSITE	FIRST SAMPLING	SECOND SAMPLING	DIFFERENCE
		<i>per cent</i>	<i>per cent</i>	<i>per cent</i>
Plot I. 1st depth.....	1	0.210	0.210	0.000
	2	0.213	0.210	0.003
	3	0.213	0.212	0.001
	4	0.211	0.213	0.002
	5	0.210	0.207	0.003
	6	0.213	0.212	0.001
	7	0.215	0.217	0.002
	8	0.221	0.219	0.002
Plot I. Second depth.....	1	0.187	0.187	0.000
	2	0.188	0.186	0.002
	3	0.187	0.187	0.000
	4	0.189	0.192	0.003
	5	0.186	0.184	0.002
	6	0.191	0.192	0.001
	7	0.193	0.193	0.000
	8	0.195	0.196	0.001
Plot II. First depth.....	1	0.166	0.161	0.005
	2	0.168	0.166	0.002
	3	0.168	0.165	0.003
	4	0.173	0.173	0.000
	5	0.161	0.159	0.002
	6	0.168	0.168	0.000
	7	0.174	0.175	0.001
	8	0.175	0.174	0.001
Plot II. Second depth.....	1	0.144	0.142	0.002
	2	0.144	0.143	0.001
	3	0.146	0.142	0.004
	4	0.148	0.149	0.001
	5	0.141	0.141	0.000
	6	0.147	0.144	0.003
	7	0.150	0.144	0.006
	8	0.150	0.149	0.001

The outstanding feature brought out by this table is that the nitrogen contents of the duplicate composites are quite uniform, no matter how these composites were selected. This indicates that, within certain limits, the number of samples entering into the composite is not so important as that

[illegible]

a - SURFACE - Second Sampling b - SURFACE - First Sampling c - SUBSOIL - First Sampling d - SUBSOIL - Second Sampling

.229 (8)	.198	.208	.187	.129
.228 (9)	.193	.199	.185	.132
.229 (9)	.192	.198	.170	.109
.229 (9)	.174	.120	.170	.082
.227	.189	.175	.147	.151
.223	.210	.174	.160	.130
.224	.190	.176	.162	.158
.230	.183	.139	.105	.104
.241	.201	.146	.101	.102
				.110
.219	.189	.176	.151	.125
.219	.178	.151	.131	.108
.229	.179	.111	.087	.108
.224	.180	.116	.092	.103
				.127
				.138
				.081
.172	.161	.145	.134	.124
.180	.150	.140	.124	.113
.221	.159	.147	.146	.132
.215	.175	.111	.130	.115
		.125	.091	.110
		.121	.091	.086
				.140
.227	.187	.168	.144	.128
.216	.200	.177	.139	.107
.236	.194	.119	.086	.087

a - SURFACE - Second Sampling b - SURFACE - First Sampling c - SUBSOIL - First Sampling d - SUBSOIL - Second Sampling

FIG. 3. NITROGEN CONTENT OF SOIL AND SUBSOIL SAMPLES CHOSEN FROM PLOT 2

FIG. 4. PROPOSED ARRANGEMENT OF BORINGS IN FUTURE SAMPLING

the samples chosen at different times to represent a plot should be selected from the same locations on the plot. With the more uniform plot the greatest variation was 0.003 per cent, equivalent to 60 pounds of nitrogen per 2,000,000 pounds of soil. With the less uniform plot the greatest variation amounted to 120 pounds per 2,000,000. The composites resulting from the eight groupings of the samples show differences in the nitrogen content of as much as 0.009 per cent, or 180 pounds per 2,000,000.

Reference to figures 2 and 3 shows that it is unsafe to have the composite made up of too few borings. In many cases the cores selected from the same location are almost identical in nitrogen content. At one point in plot 1, however, the variation amounted to 0.039 per cent and at several other points it exceeded 0.01 per cent. It is possible to so select the borings as to show very marked differences in nitrogen content in duplicate composites, provided the number of borings in the composite is not large.

It would appear from a study of these data that selecting the samples according to the arrangement in figures 2 or 3 or a combination of these two could give results very comparable with those secured from taking the entire 45 for the composite. The total number of borings for the composite would then be 17 or in the latter case 30. If the second samples were chosen from the same locations the data would indicate an almost exact duplication of analysis. It would seem logical, however, to arrange these locations uniformly over the plot. On the basis of these analyses it is safe to assume that a composite of 20 borings distributed uniformly over the plot is satisfactory, provided in subsequent sampling the locations of the borings are practically identical with those of the first sampling. The effect of cultural treatment with several years intervening will be left for a subsequent report.

CONCLUSIONS

On the basis of this study it seemed desirable to locate the samples of soil for the composite representing each plot according to the arrangement indicated in figure 4. There appears to be no argument in favor of selecting separate samples of the surface and sub-surface soil, but it does seem desirable that the samples be chosen to a depth well beyond the plow line. According to this plan the composite from each $\frac{1}{2}$ -acre plot would be made up of 20 samples, each chosen to a depth of 12 inches and arranged over the plot as indicated in the diagram. In all subsequent sampling of these plots the location of the samples and the method of choosing them should be as nearly an exact duplication of the first sampling as possible.

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