Comparison of CO_2 and $NaHCO_3$ as Extractants for Measuring Available Phosphorus in the Soil

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Since 1949 the Utah-Idaho Sugar Company has been using the CO_2 method to determine available phosphate levels in soils and to place soils in four basic groups in making recommendations for the use of phosphate fertilizers. (3) (4)[2] The limits set for the four groups are:

0— 5 ppm PO_4	—Very Low—	120 pounds P_2O_5
6—15 ppm PO_4	—Low—	80 pounds P_2O_5
16—25 ppm PO_4	—Medium—	40 pounds P_2O_5
Above 25 ppm PO_4	—High—	No added phosphate

It will be noted from the above that recommended phosphate applications varied from 0 to 120 pounds of P_2O_5 per acre depending on the available level of phosphate as indicated by the CO_2 test. In most of the areas in which the Utah-Idaho Sugar Company operates, recommendations based on the above schedule proved quite satisfactory. There were, however, some areas where discrepancies were rather frequent and where available phosphate levels appeared to be lower than was born out by field tests. Belle Fourche, South Dakota, was one of these districts.

In 1954 Sterling Olsen published a report on the use of $NaHCO_3$ as the extracting agent and gave extensive comparisons between this method, the CO_2 method and several others. Mr. Olsen's report indicated that the $NaHCO_3$ method was applicable to a wide variety of soil types and soil conditions, and that the results correlated well with crop response. (1) (2).

In view of these facts the Utah-Idaho Sugar Company decided to adopt the $NaHCO_3$ method and during the 1954 season soil samples were run by both the CO_2 and $NaHCO_3$ methods. Field trials were also run to establish response levels on sugar beets in the various areas where the company operates.

This paper is a report of the comparisons made, the phosphate levels found in Utah, Idaho, Washington, and South Dakota, and the phosphate fertilizer recommendations made on the basis of these tests.

Experimental Results

A comparison of available phosphate levels in several states as shown by the two methods of analysis is shown in Table 1 and Figures 1, 2, 3, 4. It will be observed that the percentage of soil samples falling in the classes of "low" and "medium" were essentially the same for both methods of analysis. In fact, the two methods gave very similar classification as to phosphate levels in all states except South Dakota. In South Dakota the CO_2 method of analysis showed that available phosphate level in 32 percent of the soils sampled was "very low." However, when the $NaHCO_3$ method of analysis was used, only 1 percent of the samples fell into the "very low" class. By the CO_2 method only 3 percent of the soil samples from South Dakota rated in the "high" class. The $NaHCO_3$ method showed 28 percent of the soil samples in the "high" class. This percentage with adequate

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[2] Numbers in parentheses refer to literature cited.

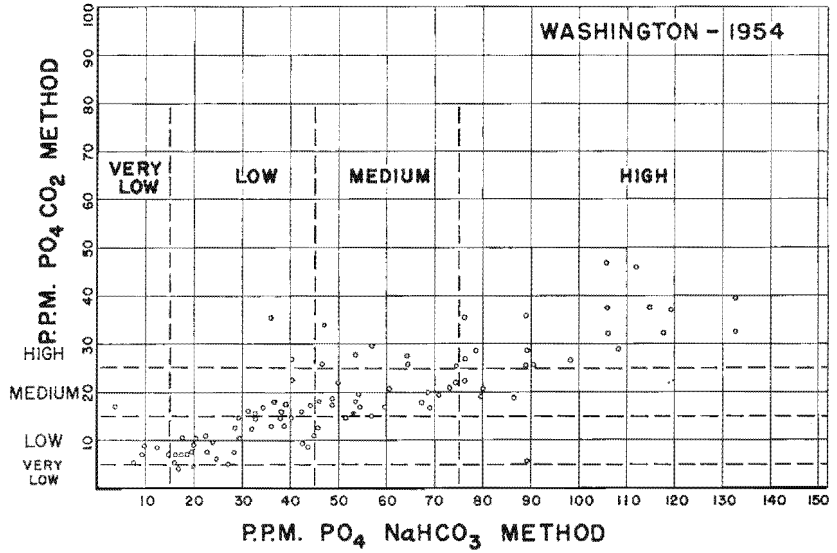

Figure 1.—This figure shows the parts per million of PO_4 from Washington soils as determined by the CO_2 method and calibrated along the left side of the chart and the $NaHCO_3$ shown along the bottom of the chart. Note that although the parts per million is approximately three times as large when determined by the $NaHCO_3$ method as when determined by the CO_2 method, there is nevertheless a close correlation between the two.

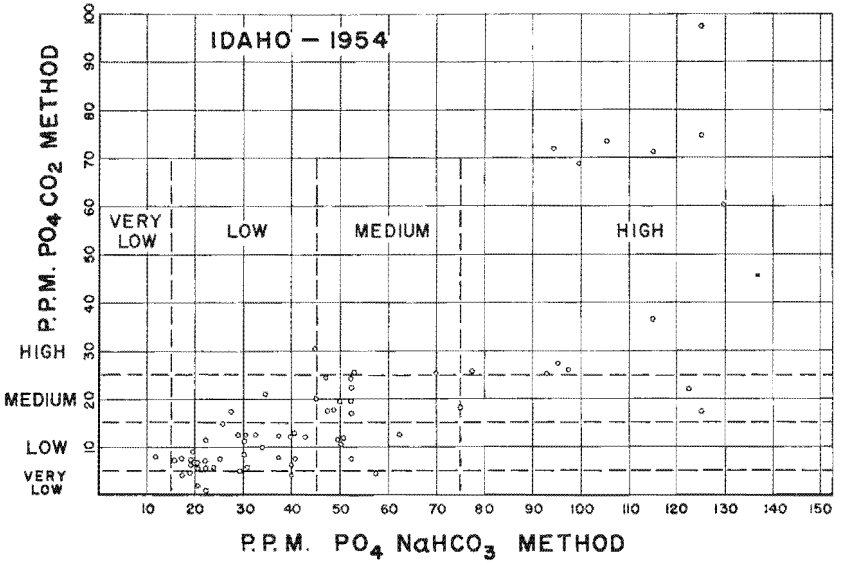

Figure 2.—This figure shows the parts per million of PO_4 from Idaho soils as determined by the CO_2 method and calibrated along the left side of the chart and the $NaHCO_3$ shown along the bottom of the chart. Note that although the parts per million is approximately three times as large when determined by the $NaHCO_3$ method as when determined by the CO_2 method, there is nevertheless a close correlation between the two.

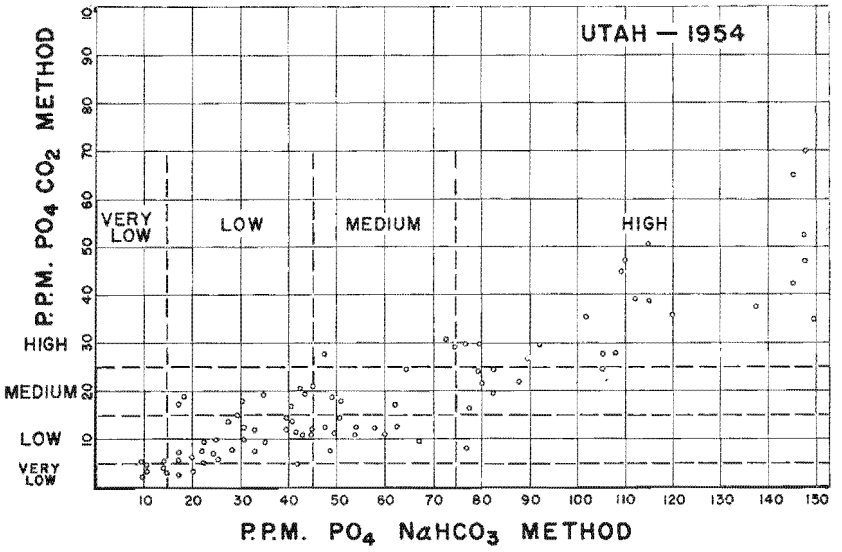

Figure 3.—This figure shows the parts per million of PO_4 from Utah soils as determined by the CO_2 method and calibrated along the left side of the chart and the $NaHCO_3$ shown along the bottom of the chart. Note that although the parts per million is approximately three times as large when determined by the $NaHCO_3$ method as when determined by the CO_2 method, there is nevertheless a close correlation between the two.

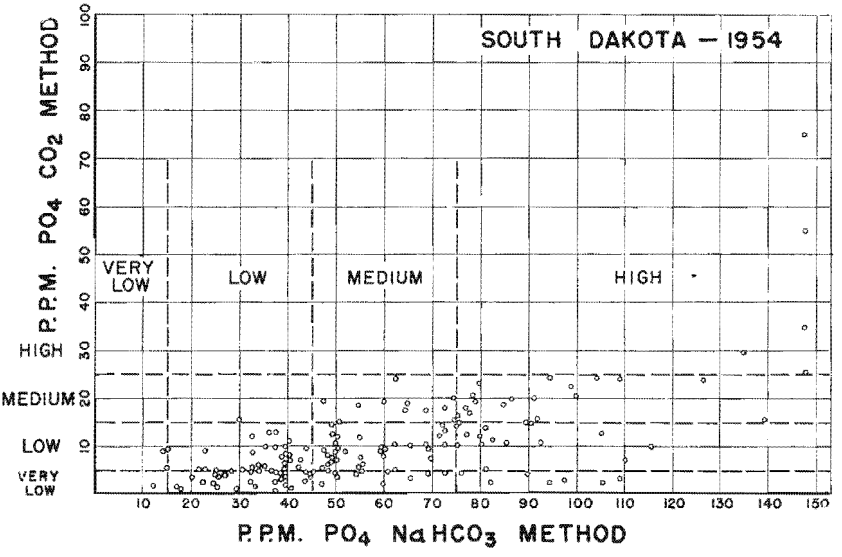

Figure 4.—This figure shows the parts per million of PO_4 from the South Dakota soils as determined by the CO_2 method and calibrated along the left side of the chart and the $NaHCO_3$ shown along the bottom of the chart. Note that in this figure there is not the close correlation of results by the two methods as there was from the soils samples taken in Washington, Idaho, and Utah.

Table 1.—Distribution of Phosphate Levels in Various Areas as Shown by Both the CO_2 and $NaHCO_3$ Extraction Methods.

Method of Analysis and Phosphate Level (PO_4)	Washington No.	%	Idaho No.	%	Utah No.	%	So. Dak. No.	%
Very Low								
CO_2 Method -0-5 ppm	0	0	7	11	10	12	52	32
$NaHCO_3$ Method 0-15 ppm	5	5	1	1	8	9	2	1
Low								
CO_2 Method 6-15 ppm	37	39	33	49	36	41	73	45
$NaHCO_3$ Method 16-45 ppm	38	40	34	50	33	38	56	35
Medium								
CO_2 Method 16-25 ppm	30	32	14	20	19	22	23	20
$NaHCO_3$ Method 46-75 ppm	26	28	17	25	18	21	58	36
High								
CO_2 Method—above 25 ppm	27	29	14	20	22	25	5	3
$NaHCO_3$ Method—above 75 ppm	25	27	16	24	28	32	46	28
Total Number of Samples	94		68		87		162	

Table 2.—Relationship Between Lack of Response to Phosphate in Field Trials and the Percentage of Soil Samples Showing Adequate Phosphate Levels.

Comparisons	Wash.	Idaho	Utah	So. Dak.	Total
No. of field tests with phosphate	68	52	77	49	246
% of tests giving response	66	71	69	73	70
% of tests giving no response	34	29	31	27	30
% of soil test with PO_4 in excess of:					
75 ppm—$NaHCO_3$ Method	27	24	32	28	28
25 ppm—CO_2 Method	29	20	25	3	16

phosphate level closely approached the percentage of field trials in South Dakota where no yield response was obtained.

The data in Table 2 show that the available PO_4 in soil samples was averaging about three times as high by the $NaHCO_3$ method as it was by the CO_2 method. Soil samples were classified as "very low," "low," "medium," or "high." The range of available PO_4 selected for each group classification by both methods of analysis is shown in Table 2. When all areas are considered, the $NaHCO_3$ method apparently classified available phosphate levels more accurately than did the CO_2 method. This was especially true in the South Dakota district where many of the soils are very heavy gumbo.

The data in Table 3 gives the number and percentage of soil samples falling in various phosphate levels. It also shows the relationship between phosphate response in field trials and phosphate levels. When soils were in the "very low" class, 100 percent of the field trials showed a phosphate response. When soils were in the "high" classification or above 75 ppm of PO_4 as shown by the $NaHCO_3$ method, then only 33 percent of the field trials showed any response to added phosphate and this response was very limited when compared with the average response of three tons per acre, which was obtained on fields where phosphate levels were classified as "low."

Recommended Fertilizer Schedule

The recommended phosphate application has been varied according to the phosphate level as shown by the soil test. This recommendation varies from none on soils classed as "high" in available phosphorus, up to 120 pounds of P_2O_5 on soils classed as "very low."

Table 3.—Phosphate Level of Soil Samples Tested and the Relationship of Phosphate Level to Phosphate Response.

Comparisons	Phosphate Level of Soil Samples			
	Very Low 0-15 ppm	Low 16-45 ppm	Medium 46-75 ppm	High Above 75 ppm
No. of soil samples in each level	16	161	119	115
% of soil samples falling in each level	4	39	29	28
% of field tests showing yield response to phosphate at each of the phosphate levels	100	74	72	33
Magnitude of the yield response per acre	2.42 tons	3.05 tons	2.53 tons	.94 tons

(Note: Phosphate levels are in terms of ppm of available PO_4 as determined by $NaHCO_3$ extraction.

Summary

Data presented in this paper would indicate that in some areas of heavy soils such as around Belle Fourche, South Dakota, the $NaHCO_3$ method of analyzing for available phosphorus is more accurate than the CO_2 method. Available phosphate levels in terms of ppm of PO_4 run about three times as high in most soils when analyzed by the $NaHCO_3$ method as when analyzed by the CO_2 method. Consequently, where 25 ppm of PO_4 in a soil was set as the top limit where phosphate fertilizer would be recommended when the CO_2 method was used, the limit has been raised to 75 ppm of PO_4 when the $NaHCO_3$ method is used. When the available phosphorus in the soil was above 75 ppm, only 33 percent of the field trials showed a yield increase, and of those showing a response the increased yield averaged .94 tons per acre. On soils where the available phosphorus was not above 45 ppm of PO_4, 74 percent of the field trials showed a yield response and the response averaged 3.05 tons per acre.

References

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