Current New Jersey Research in Chemical Soil Testing

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Correlation studies are being made between nutrient extraction by electrodialysis and plant response to variable soil fertility levels in greenhouse and field. This is a progress report.

SINCE 1933 a chemical soil-testing service of New Jersey farmers and gardeners has been conducted by the College of Agriculture of Rutgers University. A variety of salt and acid solutions have been used as extractants for the removal of the so-called "available" nutrients from the soil. Among the first solutions was that of Morgan (*13*). Another but more dilute sodium acetate solution employed for a number of years was developed by Hester, Blume, and Shelton in Virginia (*10*). For the past 11 years the method of nutrient extraction from soil samples has been electrodialysis, initiated by Purvis and Hanna (*15*). The testing procedures now in use are described in a bulletin (*8*).

Electrodialysis has been used for the extraction of exchangeable cations from soils since the early work of Bradfield (*2*), Mattson (*12*), and Humfield and Alben (*11*). Several investigators, including Harper (*9*) and Dean (*3*), have also studied the release of phosphorus from soils by electrodialysis. Dean found a higher correlation between crop response to applied phosphorus and soil measured by electrodialysis than to soil phosphorus measured by any of several other extractive means.

Tests have been under way in New Jersey for the past 12 years to compare electrodialysis with other means of nutrient extraction as well as with plant response to and uptake of nutrients in the soil. Results from a laboratory and greenhouse test conducted in 1950 (*7*) are shown in Table I. Correlation of phosphorus extracted by electrodialysis with growth and phosphorus uptake by snap beans from two soils supplied with phosphorus from eight sources compares favorably with similar correlations of phosphorus extracted by four other methods. Yield of beans and phosphorus uptake were based on the whole above-ground portion of plants. The eight sources of phosphorus were normal superphosphate, aluminum, tricalcium, iron, magnesium, and manganese phosphates, ground phosphate rock, and residual soil phosphorus. Electrodialysis and the strong acid extractant of Bray dissolved relatively more phosphorus from the soils treated with rock phosphate and tricalcium phosphate than was available to the bean plants. Other tests of this type, including *A* value determinations with phosphorus-32 have been and are being conducted.

Two types of field tests for soil-test correlation are being conducted in various soil areas of the state. The first is the usual measure of crop response to applied fertilizer. A series of tests at different sites on the same or different soil types is run with a single crop. The tests are then repeated for more than one year with the same crop but on different sites. Tests have been designed to measure the optimum amounts of phosphorus and potassium that should be applied for various soil-test levels. The plot layouts have been according to a central composite design similar to that used by Baird and Fitts (*1*) and Hader *et al.* (*6*).

In the second type of test, various crops are grown on the same site for more than one year. Rather than crop response to applied fertilizer, crop growth is measured at variable residual nutrient levels in the same soil. Field plot designs are simple complete factorials with three levels of phosphorus and potassium. Two levels of nitrogen are superimposed, but only the phosphorus and potassium soil tests are under calibration. Locations of these tests, the crops grown in 1959, and the soils at the three sites are:

Beemerville, Sussex Co., upper Piedmont. Alfalfa, corn, oats (Duchess silt loam).

New Brunswick, Middlesex Co., upper coastal plain. Peppers, potatoes, snap beans, barley (Nixon loam).

Glassboro, Gloucester Co., lower coastal plain. Asparagus, peppers (Downer sandy loam).

Tomato yields from the Glassboro plots in 1958 are summarized in Table II. High yields from low fertility treatments are due to residual phosphorus and potassium from fertilizer applications made prior to start of test. No general conclusions may be drawn from these data, as they are limited to one soil and one year. Examination of results from several such tests is necessary to formulate changes in fertilizer

Table I. Correlation of Extracted Phosphorus with Snap Bean Yield and Uptake

	Norton Silt Loam		Sassafras Sandy Loam	
Extractant	Yield	P uptake	Yield	P uptake
Electrodialysis	0.882	0.901	0.934	0.943
Na acetate, 1	0.841	0.906	0.818	0.855
Na acetate, 2	0.918	0.953	0.902	0.877
Acetic acid	0.881	0.935	0.878	0.883
Bray No. 1	0.899	0.861	0.913	0.867

Table II. Tomato Yields, Glassboro, 1958

Fertility, P	Treatment, K	Yield, Tons/Acre 1	Yield, Tons/Acre Total
Low	Low	19.7	20.6
	Medium	18.1	19.2
	High	22.3	23.3
Medium	Low	18.4	19.2
	Medium	22.6	24.0
	High	23.7	24.8
High	Low	20.3	21.4
	Medium	25.1	26.2
	High	25.0	26.3
Low	...	20.0	21.0
Medium	...	21.6	22.7
High	...	23.8	24.6
...	Low	19.5	20.4
...	Medium	21.9	23.1
...	High	23.7	24.8

recommendations. It is interesting to note a yield response to additional potassium and phosphorus, even when the residual soil level of these nutrients is sufficiently high to produce more than 20 tons of tomatoes an acre. Although information on the fertilizer requirements of a number of crops, for a variety of New Jersey soils, in relation to soil-test results has been accumulated over the past 12 years, a great deal more work remains to be done.

Results of calibration tests to date are best summarized by listing present interpretations of soil test results for various crops. Interpretations of phosphorus tests are given in Table III. Five crop groupings have been made on the basis of present information. In a general way, the crops with the lower phosphorus requirements are the perennials and the long-season grain and forage crops. Perhaps some of these crops obtain an adequate supply of phosphorus for their needs from soils with lower levels of phosphorus as measured by the soil tests. Crops that have shown growth response to added phosphorus at higher soil levels are the short-season, rapid-growing vegetables.

Potassium test interpretations are listed in Table III. Only four crop groups have been established for potassium test levels. Grains, grasses, and perennial fruits show less yield response to added potassium than do most of the vegetables grown in New Jersey. The legumes for hay or pasture respond in increased growth to added potassium at relatively high soil potassium levels.

Combining the phosphorus and potassium test interpretations has given some 26 groups of crops for recommending grade and amount of fertilizer according to soil-test results. An example of the use of these groupings is the fertilizer recommendations (Table IV) for alfalfa, clovers, and pastures at time of seeding. The fertilizer recommendation for a soil in which both the phosphorus and potassium tests are medium is the general recommendation for this or other groups of crops *(16)*. Recommendations for soils testing other than medium in phosphorus or potassium are made by adjustment of the phosphorus or potassium to be added by selection of the proper grade of fertilizer from the approved list of ratios or from straight phosphorus and potassium goods.

While the most important use of soil-test results is that of obtaining information to aid in determining the fertilizer needs of a particular crop on the particular field from which the sample for testing was taken, these results are useful for a variety of purposes. Summaries

Table III. Soil-Test Interpretation

(Pounds per acre)

Crop Group	*Very Low*	*Low*	*Medium*	*High*	*Very High*
	PHOSPHORUS				
Blueberries, cane fruit, soybeans	0–5	5–10	10–20	20–30	30
Alfalfa, clover, and grass hay and/ or pastures, corn, small grains, apples, grapes, turf	0–5	5–10	10–20	20–40	40
Peaches	0–10	10–20	20–35	35–50	50
Asparagus, beans, beets, cucurbits, crucifers, peppers, white and sweet potatoes, strawberries, young fruit trees	0–10	10–20	20–40	40–60	60
Celery, eggplants, onions, peas, sweet corn, and leafy vegetables such as lettuce, spinach, etc.	0–15	15–30	30–60	60–90	90
	POTASSIUM				
Corn, small grains, grass pasture and hay, all fruit except strawberries, soybeans, turf	0–40	40–80	80–120	120–160	160
Asparagus, beans, beets, cucurbits, crucifers, peppers, tomatoes	0–50	50–100	100–150	150–200	200
Celery, eggplants, onions, peas, sweet corn	0–75	75–125	125–200	200–300	300
Alfalfa, clover pasture, and hay	0–100	100–200	200–300	300–400	400

Table IV. Fertilizer Recommendations for Alfalfa, Clovers, and Pastures at Seeding

(Pounds per acre)

		Available Potassium in Soil									
		0		*75*		*150*		*225*		*300*	
Available P in Soil[a]		*Very Low*		*Low*		*Medium*		*High*		*Very High*	
		Fertilizer Recommendations									
0	Very low	160	P_2O_5	160	P_2O_5	160	P_2O_5	160	P_2O_5	160	P_2O_5
		160	K_2O	100	K_2O	80	K_2O	60	K_2O	30	K_2O
		400	0–20–20	350	Super	400	Super	500	Super	550	Super
		800	5–10–10	900	5–10–10	800	5–10–10	700	8–8–8	600	8–8–8
5	Low	100	P_2O_5	100	P_2O_5	100	P_2O_5	100	P_2O_5	100	P_2O_5
		160	K_2O	100	K_2O	80	K_2O	60	K_2O	30	K_2O
		300	0–20–20	1000	5–10–10	900	5–10–10	1100	5–10–5	300	Super
		700	7–7–14							600	8–8–8
10	Medium	80	P_2O_{52}	80	P_2O_5	80	P_2O_5	80	P_2O_5	80	P_2O_5
		160	K_2O	100	K_2O	80	K_2O	60	K_2O	30	K_2O
		300	0–10–20	900	5–10–10	800	5–10–10	800	5–10–10	800	5–10–10
20		700	7–7–14								
	High	60	P_2O_5	60	P_2O_5	60	P_2O_5	60	P_2O_5	60	P_2O_5
		160	K_2O	100	K_2O	80	K_2O	60	K_2O	30	K_2O
		200	Muriate	800	7–7–14	700	7–7–14	700	8–8–8	700	5–10–5
40		800	5–10–5								
	Very high	30	P_2O_5	30	P_2O_5	30	P_2O_5	30	P_2O_5	30	P_2O_5
		160	K_2O	100	K_2O	80	K_2O	60	K_2O	30	K_2O
		200	Muriate	200	Muriate	600	7–7–14	500	7–7–14	400	8–8–8
		500	8–8–8	500	8–8–8						

[a] As determined by electrodialysis at New Jersey Agricultural Experiment Station.

Table V. Soil Test Results for Tomatoes, 1958

Phosphorus	Potassium Low	Medium	High	Total
	Per Cent of Samples			
Low	7	1	3	11
Medium	5	19	4	28
High	13	14	34	61
Total	25	34	41	

Table VI. Soil Test Results in Warren County

(Per cent each soil)

Land Type Areas	Phosphorus Low	Medium	High	Potassium Low	Medium	High
Early drift						
Shale uplands	75.8	24.0	0.2	65.6	34.4	0
Limestone valleys	68.5	23.1	8.4	46.4	46.1	7.3
Gneiss highlands	86.4	10.4	3.2	59.2	32.0	8.8
Later drift						
Shale uplands	73.0	21.9	5.1	70.9	24.1	5.0
Limestone valleys	49.4	37.1	13.5	71.2	24.3	4.5
Gneiss highlands	72.7	22.1	5.2	59.7	39.6	1.3
The Moraine	61.1	25.0	13.9	48.1	43.6	8.3
Muck	6.1	21.7	72.2	3.5	23.5	73.0

from a large number of samples from different soils and crops will show areas of nutrient deficiencies, fertilizer use patterns, and probable percentage of samples, in a given area and for a given crop, requiring various grades of fertilizer. The use of summaries of soil-test results to show probable fertilizer needs for a particular crop is demonstrated in Table V. Soils used for tomatoes in New Jersey tend to be low in potassium and high in phosphorus. These data indicate that a 1–2–2 or 1–1–1 fertilizer would be recommended for about 61% of the soils used for tomatoes; 1–1–2 for some 32% of the samples; and 1–2–1 for only 7% of the soils. Fitts, Welch, and Nelson *(4)* have used this same type of data to predict fertilizer ratios needed for a particular crop in various areas of North Carolina. Only a limited number of such crop summaries have been made in New Jersey, because soil test data will be completely transferred to punch cards only as funds permit. Rather complete summaries have been made *(5, 14)* for three counties—Warren, Monmouth, and Gloucester—where recent soil surveys have been completed.

One type of summary of soil-test data that has been made is illustrated in Table VI. Phosphorus and potassium tests for Warren County have been sorted according to age of soil and type of parent material. In this county there is a rather sharp boundary between areas covered during the glacial periods. The shale soils show little difference in phosphorus or potassium levels between the two time periods. Soils of the limestone valleys have become more acid with time and as a result soils on the earlier drift are more acid, as indicated by pH tests, and have lower available phosphorus. On the other hand, these limestone soils have higher potassium in the area of the earlier drift, where a longer time of weathering and soil formation has resulted in more acid soils. These data point to the difference in the amount of weathering with time between the shale and gneiss parent materials. Highly fertilized vegetables are grown on the muck.

All soil-test calibration studies are being expanded as funds permit. Fertilizer recommendations are modified according to results of laboratory, greenhouse, and field experiments as needed to give New Jersey growers the best possible information on the fertilizer requirements of their crops and soils.

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Interpretation of Soil Tests and Application as Charted by Current Research

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Soil tests should provide information about the soil which will serve as a guide to liming and fertilization. Since the time of Liebig, the goal of agronomists has been evaluation of soil fertility and prediction of crop yield from soil tests. However, the yield of a crop (both quantity and quality) is a function of several factors, which can be expressed by the equation:

$$\text{Yield} = f(\text{crop} + \text{soil} + \text{climate} + \text{management})$$

If an index or value can be obtained for each variable, the yield can be calculated. Soil testing furnishes information about the soil variable in the equation in respect to fertility or special soil conditions. Other sources of information are needed for the other variables.