and their use is not suggested. Past work has shown that the discoloration can be controlled by proper adherence to standards of sanitation, care in handling to avoid excessive damage, and precooling and maintenance of temperatures below 50°F. during marketing. Such procedures are highly recommended.

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A COMPARISON OF QUICK TESTS ON FLORIDA SOILS

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The increased interest in soil testing during the last few years has resulted in a large number of requests for interpreting soil test data and making recommendations from data obtained by certain quick test methods. In order to make the recommendations, certain other information is needed in addition to the data. The amount of nutrients removed from a soil by different extracting solutions varies and some methods of analyses are more sensitive than others.

In order to obtain information about the quick test kits four were selected for use in analyzing a group of ten soils. In this way the data obtained could be compared with that obtained by the University of Florida, Soil Testing Laboratory.

In this discussion the term "quick tests" is used to designate those tests that can be made in either the laboratory or field by almost anyone with a small amount of equipment and without prior scientific training. They are usually visual, colorimetric tests that can be bought in sets, or kit form. Directions for making the tests and interpretation of the results are obtained with the kit. Interpretation of the soil test results are usually based on work and conditions common to the area where the kits were developed. Therefore, it is reasonable to believe that the interpretations may not hold in other areas and under other conditions.

The methods used in a laboratory, such as the Soil Testing Laboratory, are usually quantitative and much more precise. Considerable work has been conducted in the state on the correlation of these soil test data with crop responses to various fertility levels under Florida conditions. Although some of the methods used in the Soil Testing Laboratory are fast, in terms of the number of determinations that can be made in a limited time, trained personnel and expensive equipment are required.

METHOD OF PROCEDURE

The soil test kits used in this study are generally known as the Purdue, Spurway, Morgan and LaMotte test kits. As a comparison, the samples were also analyzed by the University of Florida, Soil Testing Laboratory. The methods used in the Soil Testing Laboratory are quantitative and should not be classified as quick tests (1).

In general, all the quick tests used were based on work done at different Agricultural Experiment Stations by various workers. The Purdue kit is the result of work done by the Purdue Agriculture Experiment Station and is being produced commercially by that station (2, 5). The Spurway tests were made according to instructions given by him and published by the Michigan Agricultural Experiment Station (6). Commercially it is known as the Simplex Soil Testing Outfit (7). The Morgan tests are based on the work done at the Connecticut Agriculture Experiment Station (4.) The methods used were from this publication rather than that of a later edition (3) because of certain changes in methods and because it was not possible to calculate, from the data at hand, some of the values given for the ratings of certain tests. The LaMotte kit was purchased from the La-

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Motte Chemical Products Co., Chestertown, Maryland and is based, at least in part, on the work of Morgan (9).

METHODS

All the quick test methods for pH used organic dyes as indicators. The procedures usually employed a porcelain spot plate, special porcelain black or wax paper strips for making the determinations. In each case the indicator solution was either added directly to the soil or to the soil solution. The resulting colors obtained were then compared to color charts to obtain the pH values. An indicator was chosen with a critical pH value close as possible to the pH being measured. Since the pH of the soil to be tested was not known, it was sometimes necessary to make more than one test to determine the correct indicator.

The Soil Testing Laboratory used a potentiometer and glass electrode for the pH determinations. These instruments enable an operator to make accurate pH measurements on a large number of samples in a short period of time.

The indicators, and their pH ranges, used by each method were as follows: The Purdue set employed three indicators: Bromthymol Blue (pH 5.8-7.5), Bromcresol Green (pH 3.8-5.5) and Chlorphenol Red (pH 4.8-6.2). The Spurway set employed two indicators: Bromcresol Green (pH 3.8-5.4) and Aurin (pH 6.9-8.0). The Morgan method employed three indicators for humid areas: Bromthymol Blue (pH 6.0-7.6), Chlorphenol Red (pH 5.0-6.6) and Bromcresol Green (pH 3.8-5.4). The LaMotte set used four indicators: Phenol Red (pH 6.8-8.4), Bromthymol Blue (pH 6.0-7.6), Chlorphenol Red (pH 5.2-6.8) and Bromcresol Green (pH 3.8-5.4).

The acidity of the extracting solutions and the details used in making the tests varied. The Florida, Spurway, Morgan and LaMotte systems make a single extraction for the calcium, magnesium, phosphorus and potassium determinations. The Purdue system makes a separate extraction for the phosphorus and potassium determinations but no calcium or magnesium methods were given.

The quick tests for calcium were made by precipitating with oxalic acid or sodium oxalate and reading the resulting turbidity from a chart. The magnesium was precipitated as magnesium hydroxide with titan yellow and sodium hydroxide. The resulting color changes were from light orange to peach red with increasing content of magnesium. The color was then compared with appropriate color charts to find the value or rating.

All the phosphorus methods used some modification of the Deniges method for determining small amounts of phosphorus. This method is very sensitive when the proper reagent concentrations and techniques are employed. Basically the method involves the development of a blue color when soluble phosphate is present in an acid molybdate solution that is treated with a stannous salt or stirred with metallic tin. A color chart is used for comparison in determining the phosphorus concentration. The intensity of the blue color formed is directly proportional to the concentration of phosphorus in the solution.

The quick tests for potassium were made by precipitating with sodium cobaltinitrite in the presence of ethyl alcohol. The sodium cobaltinitrite combines with the potassium present to form potassium-sodium-cobaltinitrite and a finely divided precipitate is formed when alcohol is added. The resulting turbidity is then compared to charts, in some prescribed manner.

The methods used by the Soil Testing Laboratory were quantitative and more precise than the quick tests. The calcium and potassium determinations were made on a Beckman Model B Spectrophotometer with flame attachment. The magnesium determinations were made on a Beckman Model DU Spectrophotometer with photomultiplier and flame attachment. The phosphorus method employed the same reagents as the quick tests but in different proportions and concentrations. The intensity of the blue color was then measured by means of a photoelectric colorimeter, eliminating the possibility of error due to visual reading.

REPORTING OF RESULTS

The methods of expressing the results obtained by the various tests were not uniform. Some were expressed as parts per million of the nutrient in the soil extract or in pounds per acre. The nutrient supply was also given as a relative numerical rating index or only as low, medium and high. In still other cases the results were further broken down into five classes as very low, low, medium, high and very high.

In order to have an equal number of categories for each method and to be able to make comparisons among methods, the results of all tests were interpreted as being in one of five categories. They were; very low, low, medium, high and very high. Since very little

Table 1 The Values Included in Each of the Five Categories for the Different Methods.

Relative Values*	METHODS				
	FLORIDA	PURDUE	SPURWAY	MORGAN	LAMOTTE
			pH		
VL	<5.0	<4.8	<4.5	<4.5	<4.5
L	5.1-5.5	5.0-5.6	4.6-5.5	5.0-5.5	5.0-5.5
M	5.6-6.0	5.8-6.2	5.5-6.0	5.6-6.0	5.6-6.0
H	6.1-6.5	6.4-7.0	6.0-7.5	6.1-6.5	6.1-6.5
VH	>6.6	>7.0	>7.5	>6.5	>6.5
			Calcium (ppm)		
VL	<100	-	<100	<480	<150
L	101-200	-	400	840	350
M	201-500	-	600	1200-1440	700-1000
H	501-1500	-	800	1680	1400
VH	>1500	-	>800	>1920	>2800
			Magnesium (ppm)		
VL	<25	-	<0	<2	<2
L	26-75	-	8	6	6
M	76-150	-	16	12-24	12-24
H	151-300	-	24	36	36
VH	>301	-	>24	>60	>60
			Phosphorus (ppm)		
VL	< 5	< .4	< 2	< 0.3	< 5
L	6-12	.7	4	0.96	12
M	13-25	2.2	10	1.9-3.8	25-50
H	26-50	5.4	20	5.8	75
VH	> 51	>9.0	>20	>9.6	>100
			Potassium (ppm)		
VL	< 20	< 70	<12	< 32	<50
L	21-40	140	20	56	60
M	41-80	209	40	80-96	70-110
H	81-160	>349	80	112	150
VH	> 161		>80	>128	>200

* VL - very low, L - low, M - medium, H- high and VH - very high.

Table 2
The Total Exchange Capacity, Exchangeable Bases, Percent Base Saturation, Organic Matter and Phosphorus Values Obtained for Each Soil.

Soil No.	Soil	Exchange Capacity me/100 gm.	Exchangeable Bases me/100 gms. Ca	Mg	K	Percent Base Saturation	Percent Organic Matter	Percent Total Phosphorus
1.	Lakeland fs (Virgin)	1.06	0.19	0.21	0.04	41.5	0.73	0.014
2.	Leon fs (Virgin)	7.41	0.50	0.49	0.08	14.4	4.47	0.004
3.	Hernando lfs (Virgin)	11.10	4.44	1.85	0.15	50.0	2.72	0.193
4.	Gainesville lfs (Virgin)	12.42	4.99	1.50	0.37	55.2	2.96	0.071
5.	Scranton fs (Virgin)	10.88	0.50	0.46	0.09	9.6	4.41	0.024
6.	Norfolk lfs (Virgin)	4.47	0.80	0.34	0.09	27.5	0.97	0.002
7.	Norfolk lfs (Cultivated)	4.17	1.30	0.65	0.17	50.8	1.29	0.003
8.	Tifton lfs (Cultivated)	4.52	0.75	0.31	0.10	25.7	1.41	0.008
9.	Red Bay lfs (Virgin)	3.12	0.12	0.18	0.15	14.4	1.24	0.007
10.	Red Bay lfs (Cultivated)	4.56	1.10	0.31	0.26	36.6	0.91	0.052

information was available for some methods, it was necessary for the author to make certain decisions regarding the numerical values for different categories based on experience and the information at hand. Therefore, there is the possibility that the operators may have been called upon to exercise judgment not contemplated by the developers of the method. The values decided upon for different categories for each method and test are given in Table 1.

Operators

In order to approximate the conditions under which the average person would use a quick test kit, the tests were made by operators who had no previous experience of checking the results obtained by the various methods. Each test was made by four different operators working independent of each other, although they were familiar with the general operation of a laboratory.

Soils

Ten surface soil samples (0-6") were used in this study (Table 2). They were selected to represent some of the more important agricultural soils, as well as a large part of the total area, of the state. In order to obtain additional information about the soils, total exchange capacity, exchangeable bases, percent base saturation, organic matter and phosphorus determinations were made on each sample (Table 2).

Results and Discussion

The relative values obtained by the different methods for the various soils are given in Table 3 and the analysis of variance of the data is given in Table 4.

Soil Acidity (pH)

The relative pH values given in Table 3 for each method are averages of the four values obtained by the operators. In general, the values obtained by the different methods compare rather well. However, certain variations were evident among operators for the different methods but they were not enough to be statistically significant. The greatest variations were obtained by the Purdue method with differences between operators of from 0.2 to 1.4 pH units. This was equivalent to a variation from the mean of the four values obtained by the operators of 1.6 and 16.9 percent respectively. Four of the ten soils had variations of as much as one pH unit. The overall variations obtained by operators for the LaMotte method was from 0.4 to 1.0 pH unit or a variation from the mean of values obtained by each operator of 5.9 and 15.4 percent, respectively with three of the ten soils having variations of 1.0 pH unit by the different operators. The Spurway method showed variations by the operators of from a low of 0.2 to a high of 1.0 pH unit, or a variation from the mean of values obtained by each operator of 2.1 and 12.3 percent, respectively. The Morgan method gave the smallest variations by operators ranging from a low of 0 for one soil to a high of 0.6 pH unit for four soils, or a variation from the mean of values obtained by each operator of 0 and 8.3 percent, respectively. The largest variation from the mean obtained by any operator

Table 3 The Average Soil Test Values Obtained by All Operators for the Different Methods.

Soil Number	METHODS				
	FLORIDA	PURDUE	SHUHWAY	MORGAN	LAMOTTE
			pH		
1.	L	VL	L	L	L
2.	VL	VL	VL	VL	VL
3.	M	L	M	M	H
4.	H	M	H	H	H
5.	VL	L	L	VL	VL
6.	L	L	L	L	L
7.	M	M	M	M	L
8.	L	L	L	L	L
9.	VL	L	L	VL	L
10.	M	M	M	M	L
			Calcium		
1.	VL	-	VL	VL	VL
2.	L	-	VL	VL	VL
3.	H	-	L	H	H
4.	H	-	L	H	H
5.	VL	-	VL	VL	VL
6.	VL	-	VL	VL	VL
7.	M	-	L	VL	VL
8.	VL	-	VL	VL	VL
9.	VL	-	VL	VL	VL
10.	M	-	L	L	VL
			Magnesium		
1.	VL	-	L	VL	VL
2.	L	-	M	H	H
3.	H	-	H	H	VH
4.	H	-	H	H	VH
5.	L	-	L	M	M
6.	L	-	L	M	M
7.	L	-	H	H	M
8.	L	-	L	M	M
9.	VL	-	L	L	L
10.	L	-	M	M	M
			Phosphorus		
1.	L	VH	L	M	M
2.	VL	L	L	M	M
3.	M	H	M	H	VH
4.	L	VH	L	M	H
5.	VL	H	VL	VL	VL
6.	VL	VL	VL	VL	VL
7.	VL	L	VL	M	L
8.	VL	VL	VL	VL	VL
9.	VL	VL	VL	VL	VL
10.	M	VH	M	H	VH
			Potassium		
1.	VL	VL	VL	VL	VL
2.	L	VL	VL	VL	L
3.	M	L	VL	VL	L
4.	M	H	L	L	M
5.	L	VL	VL	VL	L
6.	L	VL	VL	VL	L
7.	M	H	M	VL	M
8.	VL	L	VL	VL	L
9.	L	VL	VL	VL	L
10.	H	H	H	L	M

Table 4 Analysis of Variance

Source	df	Sum of Squares	Mean Square	F
		pH		
Soils	9	139.94	15.5494	67.003***
Test Methods	4	4.27	1.0675	4.600**
Soil x Test Methods	36	14.53	0.4036	1.739*
Operators	3	2.13	0.5338	2.300
Error	147	34.12	0.2321	
Total	199	194.99		
		Calcium		
Soils	9	116.15	12.9056	46.827***
Test Methods	3	20.55	6.8500	24.855***
Soil x Test Methods	27	44.20	1.6370	5.940***
Operators	3	1.25	0.4167	1.512
Error	117	32.25	0.2756	
Total	159	214.40		
		Magnesium		
Soils	9	131.72	14.6361	71.886***
Test Methods	3	28.92	9.6417	47.356***
Soil x Test Methods	27	16.82	0.6231	3.060***
Operators	3	7.68	2.5583	12.565***
Error	117	23.82	0.2036	
Total	159	208.96		
		Phosphorus		
Soils	9	206.48	22.9422	108.886***
Test Method	4	59.53	14.8825	70.634***
Soil x Test Methods	36	64.17	1.7825	8.460***
Operators	3	2.02	0.5050	2.397
Error	147	30.98	0.2107	
Total	199	363.18		
		Potassium		
Soils	9	128.20	14.2450	49.087***
Test Methods	4	42.43	10.6075	36.552***
Soil x Test Methods	36	44.77	1.2436	4.285***
Operators	3	4.09	1.0238	3.528**
Error	147	42.66	0.2902	
Total	199	262.15		

* Significant at 5% level of probability.
** Significant at 1% level of probability.
*** Significant at 0.1% level of probability.

for the Soil Testing Laboratory was 5.0 percent for one sample.

The analysis of variance showed that the pH values of the ten soils were very highly significant (Table 4). It also indicated that the differences obtained by the various methods were highly significant. Therefore, it would be expected that the pH values obtained by the different methods would be similar only about one percent of the time. The interaction of soils and test methods was found to be significant indicating that the test values obtained by the different methods would not change in the same order, or proportion from one soil to another. This has been confirmed by other workers (10).

Calcium and Magnesium

The soil test values obtained by the different operators for calcium and magnesium were averaged and the relative values are given for the different methods in Table 3.

The calcium values obtained by the Spurway test were considerably lower for soils 3 and 4 than the values obtained by the other methods. All of the quick test methods gave lower values for soils 7 and 10 than the Soil Testing Laboratory. The above 4 soils contained larger amounts of exchangeable calcium than the remaining 6 soils and in each case a larger percentage of the total exchange capacity was occupied by exchangeable bases (Table 2). This indicates that high calcium values are more difficult to determine by the quick test methods than are lower values.

Although the variations obtained in the calcium values by the Soil Testing Laboratory were not apparent from the relative values, there were slight variations in the data; the largest numerical variation for the four determinations was 105 parts per million for sample 3. This was actually only 6.1 percent variation from the mean of the four values. The quick test values for the sample varied from the mean of the four determinations for each of the methods by 42.8, 10.3 and 96.7 percent for the Spurway, Morgan and LaMotte methods, respectively. Although the Spurway and LaMotte values are rather large they represent the maximum variations obtained by the operators. When the data obtained for all methods was analyzed statistically, the variations obtained by the operators was not found to be significant.

The relative magnesium values obtained by the different quick test methods were higher on several of the soils than those obtained by the Soil Testing Laboratory. The variation in values obtained by operators for the different methods generally was not very great numerically but rather large percentagewise, and they were found to be very highly significant statistically. The maximum variation among determinations by the Soil Testing Laboratory was 52 parts per million for sample 4. This was equivalent to a 16.2 percent variation from the mean of the four determinations for that soil. The variations obtained for the same sample by other methods were 36.4, 42.8 and 0 percent for the Spurway, Morgan and LaMotte tests, respectively. Larger variations were obtained for the LaMotte test in some instances by the different operators. The variation was found to be as high as 84.6 percent for sample 9. The differences in values obtained by operators for the various methods were found to be very highly significant (Table 4).

The analysis of variance of the values for calcium and magnesium showed that soils and test methods were very highly significantly different (Table 4). In other words the data obtained by the different methods would be expected to be comparable only one time out of a thousand. The interaction of soils and the test methods were also very highly significant, indicating that the methods would not be expected to react in the same manner from one soil to another.

Phosphorus

The phosphorus values obtained by the four operators were averaged for each method and the relative values are given in Table 3. The values obtained by the Purdue tests were found to be higher for seven of the ten soils than those obtained by the Soil Testing Laboratory. The extremes in values obtained by different operators for the two methods varied from very low to very high. However, the values obtained by the different operators for the five methods were not significantly different (Table 4). The values obtained by the Spurway test appeared to be about the same as those obtained by the Soil Testing Laboratory. The Morgan and LaMotte test values were similar to those obtained by the Soil Testing Laboratory for four of the ten soils, but the values were considerably higher for samples 1, 2, 3, 4, 7 and 10 by these methods.

The phosphorus values obtained for most soils tended to be on the low side, making determinations more difficult, and variations of only one or two parts per million very large, percentagewise.

An analysis of variance showed that the values obtained by the different methods were very highly significant for the various soils (Table 4). Therefore, the possibility of comparing data obtained by one method with that obtained by another method by using a factor was eliminated.

Potassium

The potassium values obtained by all operators were averaged for each method and the relative values are given in Table 3. The largest variation found among determinations by the Soil Testing Laboratory was 20 parts per million for sample 4. This was equivalent to an 8.2 percent variation from the mean of the four determinations. The percent variation from the mean obtained by operators for each of the other methods was 128.6 for Spurway, 29.0 for Morgan and 0 for Purdue and LaMotte on the same sample. The percent variations from the mean for the other samples were as high as 25.0 for LaMotte and 150.0 for Purdue. The variations obtained by operators were found to be highly significant.

The analysis of variance for potassium showed that the differences in test values obtained between soils and test methods were very highly significant.

Summary

This study was undertaken to determine the relative values that may be obtained by four quick test methods on different soils and how they would compare with the values obtained by the Soil Testing Laboratory at the University of Florida. The tests were made independently by four different operators for pH and available calcium, magnesium, phosphorus and potassium.

Some of the pH methods were easier to use than others, but no particular difficulties were encountered except when the soil solution was deeply colored. The maximum variation in pH values obtained by the different operators for each method was 0.6, 1.0, 1.0 and 1.4 pH units for Morgan, LaMotte, Spurway and Purdue tests, respectively. These are rather large variations when compared to the maximum variation of only 0.2 of a pH unit obtained by the Soil Testing Laboratory with a pH meter. However, they were not found to be statistically significant. There is no doubt that an operator experienced in comparing the results obtained by a given method with the values obtained with a pH meter could improve in interpreting the tests.

The turbidity for the calcium determination was found to be rather difficult to read. This, probably, accounts for some of the large variations obtained by different operators for quick test methods. The variations from the mean of the four determinations for each method were 42.5, 10.3 and 96.7 percent for the Spurway, Morgan and LaMotte methods, respectively. The Soil Testing Laboratory obtained a maximum variation of 6.1 percent for one sample.

The magnesium color change was not very distinct for the quick test and there was a tendency for the solution to coagulate when the reagents were added if the magnesium content was very high. However, the tests can be used for obtaining an estimate of the exchangeable magnesium in the soil.

The phosphorus quick tests were probably easier to make and read than any of the others except that of pH. The actual phosphorus values obtained varied considerably for the different methods. However, much of this variation was eliminated when relative values were assigned.

The maximum variations in the potassium quick test results obtained by different operators were 25, 64, 68 and 270 parts per million, for the LaMotte, Morgan, Spurway and Purdue methods, respectively. The maximum variation obtained by the Soil Testing Laboratory was 20 parts per million. Such factors as temperature and technique are very important in making the potassium determination and should be considered when making the tests.

The results obtained by the different methods on the various soils were in very poor agreement as shown by the analysis of variance (Table 4). The differences were found to be highly significant for the pH determination and very highly significant for the calcium, potassium, magnesium and phosphorus methods. The interaction between the soils and pH methods was significant, while the interaction for all other methods was very highly significant. The relative values obtain-

ed by the different operators were not found to be significantly different for the pH, calcium and phosphorus determinations, but were highly significant for the potassium determination and very highly significant for the calcium determinations.

This clearly indicates that different methods will not give the same results on all soils. Therefore, a compensating factor can not be used for comparing data obtained by tests of this nature.

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WATERMELON SPACING AND FERTILIZATION

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General fertilizer recommendation for watermelons on non-irrigated sandy soils in Florida has been approximately 1,000 pounds per acre of 6 - 8 - 6, or its equivalent. The recommendation for irrigated sandy land has been about 2,000 pounds per acre of 6 - 8 - 6 or similar analysis. Spacings of 8-12 feet between rows and 6-8 feet between plants on the row have also been suggested (1). The importance of supplying adequate amounts of fertilizer under conditions where moisture was not a limiting factor has been recognized (2). The efficient utilization of such fertilizer could be enhanced, possibly, by spacing the plants close together. The work of Nettles and Lundy (2) indicated that the maximum productive capacity may not have been reached by fertilizing at the rate of 1,000 pounds per acre and using a spacing plan of 9 x 10 feet.

Methods

A spacing-fertilizer rate experiment was conducted at the Horticultural Unit at Gainesville, in 1958 and 1959. The variety Charleston Gray was grown at three, six, nine and 12-foot intervals on rows 10 feet apart. Each spacing treatment received 6 - 8 - 8 fertilizer at rates of 500, 1,000, 1,500 and 2,000 pounds per acre. The fertilizer was applied in a furrow to one side and slightly below seed level prior to planting. The spacing and fertilizer treatments were arranged in a factorial design and were replicated six times. Individual plots were one-sixtieth of an acre.

The 1958 crop received no additional fertilizer beyond the initial application, while the 1959 crop received additional nitrate of soda-potash (15 - 0 - 14 analysis) amounting to approximately one-third the original quantity of nitrogen and potassium applied. The topdresser was added to offset the leaching effect of heavy rainfall at and shortly after planting. The crops received adequate (perhaps excessive) moisture from rainfall or supplemental irrigation. The plants were sprayed with zineb (or maneb) weekly, or more frequently if necessary, to control foliage diseases. The melons were not pruned—all fruits set on the vines were allowed to develop. Only marketable melons were harvested, counted and weighed. The data reported refer only to melons weighing 17.5 pounds or more.

Results and Discussion

The main effects of spacing and fertilizer rates on number and average weight of melons produced are shown in Table 1. In both years the number of melons increased as the spacing between plants decreased, and apparently the maximum response was not reached. In 1959 the number of melons increased as the rate of fertilizer increased, and again the maximum

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