complete confidence that their solubridge is working properly. This can be accomplished easily by asking a druggist to prepare a standard reference solution as follows:

Dissolve 0.744 grams of dry C.P. potassium chloride in distilled water and dilute to 1 liter. When the temperature dial is set properly, the instrument should read 1.41 Millimhos/cm, or 141 Mhos/cm $\times 10^{-5}$. A slight variation from the reading such as 135 Mhos/cm $\times 10^{-5}$ will not affect the usefulness of the solubridge.

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TRANSLATING SOIL TESTS INTO QUANTITY OF FERTILIZER NEEDED

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Converting chemical soil test measurements into recommended amounts of lime and other fertilizer treatments should involve more than simple mathematical calculations. The goal of a fertility program should be to optimize economically the ability of a specific soil to supply essential nutrients for a specific crop.

Many factors affect soil fertility and productivity. Some of these factors are subject to control or change and some are not. We shall not attempt to consider all factors here. However, it should be remembered that when considering the nutritional needs of plants, the controllable, as well as the uncontrollable factors will have a bearing on the fertility program plan and the resulting quality of plants produced.

Crops vary in their nutritional requirements. Soils vary in their ability to supply those nutrients needed to satisfy those requirements. Climatic factors affect crop growth and fertility response as well as management and cultural practices. Standardization of fertilizer recommendations is, therefore, not practical, and we shall not attempt to recommend rates for a specific crop or situation. Our objective simply is to explain certain soil test data and to provide guidelines for translating these into quantities of fertilizer needed to achieve specified levels of nutrient availability.

Colloidal complex. To use and understand soil analysis, we need to understand the importance of the colloidal complex.

The word colloid comes from the Greek word "kolla," meaning glue-like. When used in soil descriptions, it identifies those minute, plastic, sticky portions of the soil having large surface areas in comparison to diameter. Soil colloids show an attraction for base elements (carrying positive charge) and have the capacity to trade or exchange one base element for another. From the complex interactions among soil colloids, the soil solution, and plant roots, we derive the term "colloidal complex."

So, when we speak of the colloidal properties of the soil, we mean the ability of the soil to hold, by adsorption, various plant food elements and to release or exchange these elements under certain conditions. These elements include potassium, magnesium, calcium, manganese, iron, sodium, copper, zinc and others.

It is through these processes of adsorption and exchange that the colloidal complex can be increased in fertility potential through soil treatments. Plants exchange hydrogen for the nutrient elements they need as their roots make contact with the colloidal surfaces or the surrounding soil solution. Cations that are not adsorbed to the colloidal mass of the soil can be removed by leaching when water percolates through the soil. Thus, as a soil becomes depleted through leaching and cropping, the quantity of hydrogen ions on the colloids goes up and the quantity of the other elements goes down. Fertilization becomes a problem of replacing the hydrogen again with the proper amounts and balance of the other elements.

Terms and measurements. Following are some of the terms and measurements given on most soil test reports.

Cation Exchange Capacity, CEC, is the ability of a soil to adsorb and exchange cations (positively charged ions or atoms of the base elements mentioned above). The unit of chemical measurement used is milliequivalents (meq) per 100 grams of soil. To be useful on a field basis in determining the pounds of a nutrient needed per acre, the meq measurements need to be converted into pounds per acre. Meq is a capacity measurement and meq's of calcium, magnesium and potassium differ in weight. Following are some useful conversion factors:

1 meq Ca per 100 grams of soil = 200 ppm

1 meq Mg per 100 grams of soil = 120 ppm

1 meq K per 100 grams of soil = 390 ppm

Parts per million (ppm) is the measurement used to report nutrient elements. To convert ppm to pounds per acre of the elemental form multiply by 2. This is based on the assumption that the average weight of 1 acre of soil to a depth of 6 2/3 inches is 2,000,000 pounds. For deeper tillage use a proportionally higher multiple. Fertilizer phosphorus (P) usually is discussed in terms of P_2O_5 because this is the way it is guaranteed on the fertilizer bag. To convert ppm P to pounds per acre P_2O_5, multiply by 4.6. Fertilizer potash (K) is usually discussed in terms of K_2O because this is the way it is guaranteed on the bag. To convert ppm K to pounds per acre K_2O, multiply by 2.4

Soil pH is the measure of activity of the hydrogen ion. It is useful in interpreting soil conditions that help or hinder plant growth as it especially affects availability of nutrients.

Buffer pH measures the total soluble and exchangeable hydrogen and aluminum; that is, it measures total acidity rather than just active acidity. Buffer pH is used only to determine lime requirement and should not be confused with soil water pH. Since it is known how much acid is required to lower the buffer solution to a given pH level, lime requirements may be determined from prepared tables similar to Table 1.

Table 1. Tons/acre limestone to adjust soil to pH 6.5

	Mineral soils		Organic soils	
Buffer pH	Plow depth 6 2/3 inches	Plow depth 9 inches	Plow depth 6 2/3 inches	Plow depth 9 inches
7.0	none	none	0	0
6.9	none	none	0	0
6.8	1	1.5	0	0
6.7	1.5	2	0	0
6.6	2.0	3	0	0
6.5	2.5	4	0	0
6.4	3.0	4.5	1	1½
6.3	3.5	5	2	3
6.2	4.0	6	2½	3½
6.1	4.5	7	3	4½
6.0	5.5	8	4	6
5.9	6.0	9	4½	6½
5.8	6.5	10	5	7½
5.7	7.0	11	5½	8
5.6	8.0	12	6	9
5.5	9.0	13	6½	10

Determining the soil need for cations. The balance that soil scientists recommend for the exchange complex is 65 to 75 percent calcium, 10 to 15 percent magnesium, and 2 to 7 percent potassium. Table 2 gives the ppm and pounds of each required per acre to give this balance in soils of different exchange capacities.

The needs of a particular soil sample area are determined by subtracting the amount of the element present as shown by the soil test, from the amount recommended in Table 2 for a soil of the same cation exchange capacity (meq/100 gm). If fertilizer is applied in excess of cation exchange capacity, soluble salts damage may result.

Three considerations are involved in determining soil needs for the three major cations: (1) The cation exchange ca-

Table 2. *Balanced soil saturation of potassium, magnesium and calcium.* Parts per million necessary to balance the exchange complex of the soil to the final values of 2-7% potassium, 10-15% magnesium and 75% calcium. To convert to pounds per acre multiply by 2.

CEC meq/100 gms soil	For very high yields or high K requirement crops 2½-7%	For normal cropping Potash 2-5%	Magnesium 10-15%	Calcium 75%
50	488	390	600	7500
48	468	375	576	7200
46	449	359	552	6900
44	433	349	528	6600
42	419	344	504	6300
40	406	338	480	6000
38	397	331	456	5700
36	388	323	432	5400
34	377	314	408	5100
32	364	304	384	4800
30	351	292	360	4500
29	345	284	348	4350
28	339	274	336	4200
27	332	264	324	4050
26	325	254	312	3900
25	317	244	300	3750
24	309	234	288	3600
23	300	224	275	3450
22	292	215	263	3300
21	282	205	252	3150
20	275	195	240	3000
19	270	192	236	2850
18	267	187	230	2700
17	262	182	225	2550
16	256	176	218	2400
15	248	170	210	2250
14	240	164	202	2100
13	231	158	193	1950
12	220	152	183	1800
11	208	147	172	1650
10	195	141	160	1500
9	187	135	148	1350
8	177	129	135	1200
7	164	123	121	1050
6	148	117	106	900
5	130	108	90	750
4	110	85	75	600

pacity. (2) The ratio of these elements. (3) The degree of saturation desired. The cation exchange capacity is, for practical purposes, a fixed amount in a given soil. But we can change the ratios among the elements within this total to achieve an adequate blend of the three nutritionally important cations (K, Ca, Mg).

In most instances it is not necessary nor economically desirable to saturate the exchange complex completely with the exchangeable base elements. An 80 to 90 percent saturation of the exchange capacity with a balanced ratio of exchangeable bases will usually be adequate for high yields of most crops. The following example illustrates the calculations used to determine fertilizer requirements.

Example: A soil with CEC = 10 meq/100 grams soil; a potassium reading of 145 ppm; the crop demands high potassium.

Desired potassium level for 10 meq soil, Table 2	195 ppm
Value found (from soil report)	145 ppm
Deficient (to be applied)	50 ppm
Conversion from ppm K to pounds K_2O per acre	×2.4
Annual needs =	120 pounds K_2O

Determining the soil need for anions. Nitrogen, phosphorus, and sulfur are acid-forming materials, or anions, and must be considered as special cases. While many chemical forms of nitrogen, phosphorus, and sulfur exist in the soil, it is principally in the form of nitrate, NO_3^-; orthophosphate $H_2PO_4^-$; and sulfate, SO_4^{--} that plants can utilize these negatively charged elements.

Processes by which nitrogen, phosphorus, and sulfur are converted into nitrate, phosphate, and sulfate from other chemical forms require soil bacteria. Organic matter in the soil supplies food for bacteria and, therefore, the amount present becomes a matter of significant importance.

Estimating nitrogen needs. The most important factor in determining the nitrogen need is the crop to be grown. Wide differences of opinion exist concerning N needs of nursery crops. We suggest 150 to 300 pounds N per acre per year for field-grown stock, with higher rates for lighter soils and high density plantings. For container crops, 800 to 1600 pounds per acre per year are suggested. Many growers and researchers use 2000 pounds or more.

Most field soils are not analyzed for nitrogen. The amounts suggested above are applied in 2 or 3 applications. We try to apply a maximum of 120 pounds per acre of soluble nitrogen (N) plus soluble potash (K_2O) per application to avoid fertilizer burn from excessive salts. If higher rates per application are desirable, use slow-release nitrogen sources for part of the N applied.

Supplying phosphorus. The addition of phosphorus should have a threefold purpose: (1) To furnish an active form of phosphorus as a starter fertilizer for immediate stimulation of the seedling or liner, (2) to provide a continuing supply of available phosphorus, (3) to insure a good reserve supply of phosphorus. There are several methods used to determine phosphorus in soils. Weak Bray Phosphorus (P_1) determines readily soluble phosphorus. A level of 22 to 30 ppm P, or 100 to 130 pounds of P_2O_5 or more per acre, by this test is theoretically a desirable level for average production of most crops. It is important to remember that in actual practice many factors may affect soil and crop nutrient solubility. The Strong Bray Phosphorus (P_2) test reveals water soluble phosphate, weak acid soluble phosphate and a small amount of the active reserve phosphate. In general if the amount of phosphorus determined by this method is 44 ppm P or 200 pounds P_2O_5 or over, it may be assumed that there is enough phosphorus for at least average crop production.

To convert ppm phosphorus (P) on soil test reports to pounds per acre P_2O_5 multiply by 4.6.

Example: 30 ppm P = 138 pounds/acre P_2O_5
(30 × 4.6 = 138)

Quick reference. Table 3 is a quick reference guide for translating soil test readings into quantity of lime and fertilizer needed. There are no universally best methods or materials to use in applying fertilizer for nursery crop production. This should be kept firmly in mind when applying, writing or interpreting fertilizer recommendations. Local conditions or individual circumstances can alter any fertilizer program amounts, methods or kinds.

Soil testing. Chemical analysis of soils is an important tool for developing successful soil fertility programs. But do not expect one soil analysis to solve all of your problems. Sampling on a regular basis, coupled with detailed record keeping, will provide valuable information for maximizing benefits from fertilizer applications. In addition, these records will point out slowly developing imbalances before they become major problems.

There are many good soils laboratories. It is important to choose a good one and stick with that one. Not all labs use the same analytical procedures or reporting systems. Direct comparisons between labs may not be possible. By switching labs, continuity of information may be lost. Since you may not always wish to buy fertilizer from the same firm, use an independent laboratory or state laboratory. They have no inclination to slant recommendations to fit their product line.

Table 3. Quick reference guide for translating soil test readings into quantity of lime and fertilizer needed.

Measurement for	Desired level	How to adjust
pH	6.5 (for most crops)	Use buffer pH from soil test and refer to chart for lime needed.
Nitrogen (N) (usually not given)	Varies with crop	Add annual requirement each year - split applications.
Phosphorus (P)		
Weak Bray (P_1)	30 ppm	Desired reading = 30 ppm Subtract soil test reading − Xppm Quantity to add = Yppm Multiply Y times 4.6 to get lbs. P_2O_5 per acre per year.
Strong Bray (P_2)	60 ppm	Not necessary to figure both P_1 and P_2 the same year. Adjust P_2 at time of soil preparation using above calculations with a desired reading of 60 ppm.
Potassium (K) Magnesium (Mg) Calcium (Ca)	Varies with CEC. Refer to table showing balance soil saturations of K, Mg, and Ca to get ppm of each required for your particular soil CEC.	ppm from table = X ppm Subtract soil test reading − Y ppm Quantity to add = Z ppm For K multiply Z ppm times 2.4 to get lbs./acre K_2O needed per year. For Mg and Ca multiply Z times 2 to get lbs./acre/year.

This information summarizes methods used for determining optimum amounts of fertilizer to be applied to field soils. This is similar to information for container growing presented by George McVey in a very good paper published in the 1977 IPPS Proceedings (1). Thus, it is hoped that these two papers will provide guidelines for many of your fertilization programs.

LITERATURE CITED

1. McVey, George R. 1977. How soil chemistry can work for you. *Proc. Int. Plant Prop. Soc.* 27:277-284.

QUESTIONS FOLLOWING MEDIA TEST FORUM

JOHN MEACHAM: Question for Gerald Smith. Does it matter how wet or how dry the soil in containers is when the water for the test is added?

GERALD SMITH: Some moisture is required, but soil should not be saturated. Excessive amounts of H_2O will cause more dilution. If 2 parts of H_2O are added to a large amount of H_2O in the soil, it might make a 10 per cent difference.

TED RICHARDSON: Question for Gerald Smith. I would like to know the effect of slow release fertilizer on the soluble salts test.

GERALD SMITH: Even after shaking soil 100 times, there is probably no movement of Osmocote during the testing period. Urea formaldehyde would give no appreciable increase. All you are measuring is what is available at this time, not what will be available 2 weeks from today.

VIVIAN MUNDAY: Wouldn't that give the overall picture? The effect today with slow release formulations should be the same as any other during the release period.

GERALD SMITH: Yes, the advantage of slow release fertilizer is maintenance of an even level of fertility.

BRYSON JAMES: I believe you will get a reading of Osmocote on soluble salts test because of the laboratory's grinding process. Thus, Osmocote gives a high reading because it is all released. Urea formaldehyde is not affected because bacterial action is required for release. Grinding or water have no effect on urea formaldehyde.

JAKE TINGA: Isn't it possible to make a mistake with Osmocote in the soil by thinking fertilizer is needed when it is not?

GERALD SMITH: Yes, which is another reason to keep records of what was put on and when.

RICHARD AMMON: Then we are discussing all salts; there is no indication of which ones are present?

GERALD SMITH: That is true. The salts could be from the water.

JAKE TINGA: Question for Bryson James: Would a test emphasize magnesium when there was an acute magnesium shortage?

BRYSON JAMES: The balance of nutrients in the soil complex is important. If there is a very low per cent base saturation of magnesium yet phosphorus and calcium are very high, there could be magnesium deficiency even though the ppm reading is good. If there is a 3:1 ratio of potash to magnesium, there will be a magnesium deficiency anyway. To correct this, add dolomite limestone, which contains both calcium and magnesium carbonate, or add epsom salts (magnesium sulfate). Magnesium is a highly ionizable salt; therefore, watch the amount. Be sure to use the CEC and know what it means. Sandy soils will give a low CEC.

WILEY ROACH: Question for Bryson James: Would one application of 13-13-13 give enough phosphorus and potassium in bark:sand to be adequate for one season?

BRYSON JAMES: It is possible to apply all at one time if enough is put on. Soluble salts have no influence on CEC. Humus and organic matter have 3 to 4 times as much effect. Clay also has a high CEC. A good CEC range for bark:sand is 6 to 11. It is possible to add the nutrients when mixing soil, although this will probably not provide enough potash for the long term. A good fertilizer ratio to use is 3½ to 4 to 1 to 1.

WILEY ROACH: So if 13-13-13 is added to soil it might be necessary later on to go back and add potash and nitrogen.

BRYSON JAMES: That is correct.

FRED MAY: Is a pH of 6 to 6.5 ideal for azaleas?

BRYSON JAMES: No, it is a good range for general growing. 5.5 is probably as high as is practical with bark. The balance of ions is more important. Because of the high CEC of bark, it is not practical to adjust the pH.

METHODS USED TO APPLY FERTILIZER TO CONTAINERS AT GOOCHLAND NURSERIES

R.E. "ED" BROWN

Goochland Nurseries, Inc.
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All of our container-grown plants are fertilized with dry fertilizer applied by hand. Water soluble fertilizer is used on our liners.

We machine pot all of our 1 gallon and 3 gallon containers and hand pot 7 and 15 gallon containers.

We buy our potting mix already prepared. This consists of three parts local peat, one part builders' sand, and two parts cypress shavings; 110 lbs Hy-cal lime, 70 lbs dolomite, 72 lbs Perk minor element mix and 5 lbs chlordane are added to an 18 yard load of the potting mix. Fertilizer is applied to one gallon containers by using a plastic teaspoon, which holds ½ ounce of 6-6-6 or Osmocote. The first application is made within a few