Prunus subhirtella 'Pendula' — Watch for one or two strong shoots that aren't weeping.

Quercus species

Work hard to get a central leader

Head back the occasional wild branch.

Lift branches

Tilia species

Watch for leader bent over; prune back to straight bud.

Tilia cordata and *T. cordata* 'Greenspire' (P.P. 2086) — Occasionally head back some branches.

Thin out branches from main stem at least 6-8 inches apart vertically or 120° radially. Prune to central leader. Watch for bad crotch and correct.

Tilia × *euchlora* — Head back. Thin out some branches. Watch bad crotches.

Tilia × *euchlora* 'Redmond' — Head back, especially strong lower branches which tend to crowd main stem and inhibit lateral branching from main stem.

Trim to outside bud since these strong branches tend to grow tight to stem.

HOW SOIL CHEMISTRY CAN WORK FOR YOU

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Developing maximum plant quality with minimum cost can only be realized by proper monitoring of the nutrient level in the soil. An understanding of the optimum nutrient levels and balance in the soil will prevent "hidden hunger" or phytotoxicity, which can happen to even the best grower of containerized nursery stock.

Proper selection of media is essential. A guaranteed supply of uniform ingredients (media and fertilizer) which will provide proper drainage and porosity is needed. Media containing heavy metals or other toxic compounds should be avoided.

A representative sample of each component in the mix and a composite sample of the final mixture, before any nutrients are added, should be submitted for analysis. The analysis of the individual components will provide information on which fraction is providing the most nutrients to the final product. Nutrients should be added to the medium based on the soil analysis. Excess or deficiency of nutrients can cause an imbalance, which can result in abnormal plant growth. The optimum balance of cations (H, K, Mg, Ca and Na) for maximum growth is shown in Table 1.

Modifying the soil chemistry in the medium prior to planting is the ideal time to make adjustments. Topdress applications are time consuming and are less effective. The pH and

Table 1. Cation Exchange Capacity (CEC) and optimum balance of cations for maximum nutrient uptake.

CEC Range	Optimum % Base Saturation				
	H[1]	K	Mg	Ca[1]	Na
0 - 5	0-5	6.8-7.0	15-20	65-75	0-5
5 -10	0-5	6.0-7.0	15-20	65-75	0-5
10 - 15	0-5	5.0-7.0	15-20	65-75	0-5
15 - 20	0-5	3.0-7.0	15-20	65-75	0-5
20+	0-5	2.0-7.0	15-20	65-75	0-5

[1] For ericacious plants the optimum range for hydrogen will increase to 15-25 and the optimum range for calcium will drop to 50-65.

nutrient level can be maintained for a number of months after potting if proper nutrients are selected.

Selection of the nutrient ranges which result in poor, good and excellent growth have been under evaluation at Scotts using many soil mixtures and locations throughout the U.S. and Canada. These ranges provide guidelines for proper fertilization programs and practices. Interpretation of the results requires some experience, however.

Sampling Procedures. Prior to potting, a representative sample of the medium can be obtained by collecting a grab sample from 15 to 20 locations in the stack. Mix these samples vigorously in a clean plastic bucket, then remove a one pound sample for analysis.

After potting, sampling frequency will vary depending on the objectives. It is advisable to follow pH, buffer pH, NO_3 and soluble salts on a 2 to 3 week basis. Analysis of major, secondary and minor elements can be done less frequently (every 3 to 4 months) unless nutrient deficiencies or excesses are expected, then the frequency should be tightened up (every month). Collect a minimum of 10 soil samples from the area in question. Remove the pot from the soil ball and select a soil sample as close to the middle of the ball as possible. Place the soil samples in a clean plastic bucket, mix vigorously, and remove one pound of soil for analysis.

Soil Analysis. Select a reputable soil lab which can provide a short turn around time of the information requested. The nutrient ranges shown below were determined by the following procedures: *If other procedures are followed, the nutrient ranges reported in this paper are not meaningful.*

Nutrient	Procedure
NO_3	Water/specific ion electrode
P	BRAY P-1
K	Neutral ammonium acetate
Ca	Neutral ammonium acetate
Mg	Neutral ammonium acetate
Minors	DTPA

A number of factors should be considered in interpreting soil analysis and making recommendations (Table 2). Other chemical characteristics of major, secondary and minor elements are shown below.

Table 2. Factors to consider in interpreting soil analysis.

pH:	Dramatically affects minor element availability, particularly manganese and iron.
Soluble Salts:	Critical during the establishment phase.
Phosphorus:	Critical during the establishment phase. High levels (100 ppm) can tie up Fe, Mn, Cu and Zn.
Potassium:	High levels (300 ppm) can suppress Ca, Mg, NH_4 and Mn uptake.
Calcium:	High levels (4000 ppm) can suppress K, Mg and B uptake.
Magnesium:	High levels (600 ppm) can suppress K and Ca uptake.
Sodium:	High levels (500 ppm) can suppress K uptake and cause deflocculation of the soil.
Sulfur:	Increases availability of B, Cu, Fe, Mn and Zn.
Zinc:	High levels (12 ppm) can suppress Mn and Fe uptake.
Manganese:	High levels (48 ppm) can suppress Fe uptake.
Copper:	High levels (10 ppm) can suppress Mn and Fe uptake.
Iron:	High levels (50 ppm) can suppress Mn and Zn uptake.
Boron:	Liming strongly acid soils may suppress B uptake. High levels (9 ppm) can be very phytotoxic.

I. Major Elements (See Table 3)

A. *Nitrogen*

1. Soil analysis is of little value unless the chemical extraction is done immediately after sampling since this nutrient fluctuates dramatically during storage.

2. Lime and nitrogen applications should be spaced two weeks apart to avoid nitrogen loss by volatilization.

3. Soil with a low CEC (less than 10) are prone to leaching of nitrates and ammoniacal nitrogen. To avoid leaching losses, use a slow release source of nitrogen.

B. *Phosphorus*

1. Maximum phosphorus availability to the plant is realized between a pH of 6.2 and 6.7. Cool soils (less than 50°F), high levels of iron, manganese, zinc, copper, aluminum, calcium and magnesium reduce phosphorus availability.

2. If phosphorus and lime are in intimate contact, phosphorus availability is greatly reduced.

3. If minor elements are low in the soil, deficiencies can be induced more easily when phosphorus levels are high.

C. *Potassium*

1. Under increased moisture tension (dry soil) the concentration of calcium and magnesium in the soil increases which can depress potassium uptake.

2. Maximum potassium availability occurs above pH 6.0. Below pH 6.0 availability of potassium decreases rapidly.

3. High levels of potassium (300 ppm) can inhibit the uptake of calcium, magnesium, ammonium and manganese, particularly if these elements are low in the soil.

Table 3. N, P & K recommendations for supplementing potting media used for growing woody ornamental plants.

				Corrective Treatments[1]	
				Incorporation	Top Dress
		Range	ppm	lbs/cubic yard	tsp/1 gal. can
Nitrogen	NO_3-N	VL	0-10	6	1-1/2
		L	11-30	4	1
		M	31-50	2	1/2
		H	51-80	0	0
Phosphorus	P	VL	0-6	6	1-1/2
		L	7-12	4	1
		M	13-25	2	1/2
		H	26-50	0	0
Potassium	K	VL	0-22	6	1-1/2
		L	23-45	4	1
		M	46-90	2	1/2
		H	91-181	0	0

[1] Based on 25-10-10. Rates would vary when using another analysis fertilizer.

II. Secondary Elements (See Table 4)

A. *Calcium*

1. If the ratio of calcium/magnesium exceeds 5/1 or calcium/potassium exceeds 20/1 (based on the percent base saturation), additional magnesium and potassium will be needed to counter the high calcium levels which can block potassium and magnesium uptake.

B. *Magnesium*

1. If the ratio of magnesium to potassium is less than 3/1 (based on percent base saturation) then magnesium deficiencies may be induced by potassium suppression of magnesium uptake.

III. Minor Elements (See Tables 5 and 6)

A. *Boron*

1. Under climatic conditions which lead to the development of strongly acid soils, boron is readily leached from the soil.

2. High rates of nitrogen, potassium and lime can induce boron deficiencies.

Table 4. Ca and Mg recommendations for supplementing potting media used for growing woody ornamental plants.

				Corrective Treatments[1]	
				Incorporation	Top Dress
		Range	ppm	lbs./cubic yard	tsp./1 gal. can
Calcium	Ca	VL	0-150	18[2]	3[2]
		L	151-250	12	2
		M	251-500	6	1
		H	501-1500	0	0
Magnesium	Mg	VL	0-62	10[3]	3[3]
		L	63-113	7	2
		M	114-213	3	1
		H	214-362	0	0

[1] If soil is deficient in calcium and magnesium use dolomitic limestone at rates indicated for calcium.
[2] Ag ground limestone (30-40% Ca)
[3] Magnesium sulfate (10% Mg)

B. *Copper*

1. The availability of copper in the soil decreases as the organic content increases.

2. A low level of copper in the soil can prevent the normal uptake of potassium.

3. Plants are more responsive to copper when soil phosphorus levels are medium to low.

C. *Iron*

1. Iron availability is reduced by high soil pH, presence of calcium carbonate, high phosphates, manganese, copper or zinc in the soil or plant, high soil moisture, low soil temperature and soil compaction.

D. *Manganese*

1. Manganese deficiency is more severe on high organic soils during the cool spring particularly if soils are waterlogged.

2. Manganese deficiencies are largely a result of soil pH levels above 6.8, but it can be induced by an imbalance of calcium, magnesium and ferrous iron. In soils with a low CEC (less than 5.0) manganese can leach readily from the soil.

E. *Zinc*

1. Zinc deficiency is often associated with cool, wet spring weather.

2. Overliming can bring about zinc deficiency, particularly on soils high in natural phosphates.

3. Heavy applications of phosphates reduce zinc absorption and translocation.

Table 5. Iron, manganese and zinc recommendations for supplementing potting media used for growing woody ornamental plants.

		Range	ppm	Corrective Treatments[1] Incorporation gms./cubic yard[1]	Top Dress tsp./1 gal. can[2]
Iron	Fe	VL	0-6	80	1
		L	7-12	40	1/2
		M	13-18	20	1/4
		H	19-24	0	0
Manganese	Mn	VL	0-6	32	1
		L	7-12	16	1/2
		M	13-18	8	1/4
		H	19-24	0	0
Zinc	Zn	VL	0-1	36	1
		L	1-2	18	1/2
		M	2-4	9	1/4
		H	4-6	0	0

[1] Use iron sulfate, manganese sulfate and zinc sulfate or a complete minor element package as found in 24-9-9 plus minors. The very low range (VL) can be corrected by the addition of 4# of 24-9-9 plus minors/cubic yard.

[2] To prevent deficiencies use 24-9-9 plus minors.

Table 6. Boron and copper recommendations for supplementing potting media for growing woody ornamental plants.

		Range	ppm	Corrective Treatments[1] Incorporation gms./cubic yard	Top Dress tsp./1 gal. can
Boron	B	VL	0-.20	36	1
		L	0.21-1.00	18	1/2
		M	1.01-3.00	9	1/4
		H	3.01-6.00	0	0
Copper	Cu	VL	0-0.6	32	1
		L	0.61-1.20	16	1/2
		M	1.21-1.80	8	1/4
		H	1.81-2.40	0	0

[1] Use calcium meta borate and copper sulfate or a complete minor element package as found in 24-9-9 plus minors. The very low range (VL) can be corrected by the addition of 4# of 24-9-9 plus minors/cubic yard.

IV. Soluble Salts (See Table 7)

Soluble salt levels (total soluble minerals) can be used as a tool to determine excess or deficiency of nutrients. When the soluble salt level is very low or excessively high, plant growth is often very poor. High salt levels can be leached from the rooting media by heavy watering and low salt levels can be increased by adjusting your fertilization program.

As shown in Table 7, soluble salt ranges vary with plant age. As the plant matures higher soluble salt levels can be tolerated before plant injury occurs.

V. Controlling the pH (See Tables 8 and 9)

Table 7. Soluble salt ranges of potting media used for growing woody ornamental plants.[1]

Range[2]	Seed or Cutting	Seedling or Rooted Cutting	Established Plant
	Millimhos/Cm		
VL	0.01	0.05	0.15
L	0.05	0.15	0.45
M	0.15	0.45	0.90
H	0.45	0.90	1.80
E	0.90	1.80	2.70

[1] Based on 2/1 water/soil extraction
[2] Very low (VL), low (L), medium (M), high (H), excessive (E)

Controlling the pH of the potting medium can be very difficult but if done correctly the rewards are far reaching. It is desirable to incorporate the acidulating or alkalating agent at potting time in order to realize maximum benefit. Surface applications may be essential, however, before the crop matures. If you are using hardwood bark in the potting media, the pH tends to drift to the alkaline side. In addition if you have a source of water which contains calcium, magnesium or sodium, the pH will increase.

Certain nitrogen sources are also acidulating (e.g. ammonium nitrate, ammonium sulfate) while others are alkalating (e.g. potassium nitrate, calcium nitrate). Some slow release sources will drop the pH 1 to 2 pH units while other sources have little impact.

Soil pH can be modified to obtain the pH level desired as shown in Table 8 and 9. If the potting medium contains hardwood bark, acidulating is very difficult.

Table 8. Making soil more acidic.[1,2,3]

	Desired pH			
	5.5		6.5	
Present	Incorporation	Top Dress	Incorporation	Top Dress
pH	lbs./cubic yard	tsp./1 gal. can	lbs./cubic yard	tsp./1 gal. can
8.5	3.00	2/3	2.00	2/5
8.0	2.40	1/2	1.50	1/3
7.5	1.80	2/5	1.00	1/4
7.0	1.50	1/3	0.50	1/9
6.5	1.00	1/4	—	—
6.0	0.50	1/9	—	—

[1] Agrisul (90% granular sulfur)
[2] Double the rate if mix contains greater than 50% hardwood bark.
[3] Repeat application every six months until desired pH is obtained.

Table 9. Making soils more alkaline.[1,2]

Buffer pH[3]	Desired pH 5.5 Incorporation lbs./cubic yard	5.5 Top Dress tsp./1 gal. can	Desired pH 6.5 Incorporation lbs./cubic yard	6.5 Top Dress tsp./1 gal. can
7.4	0.0	0	0.0	0
7.2	0.4	1/10	0.5	1/10
7.0	0.7	1/8	1.0	2/10
6.8	1.4	1/4	2.0	3/10
6.6	3.8	7/10	5.4	1.0
6.4	6.1	1.0	8.7	1.4
6.2	8.4	1.4	12.0	2.0
6.0	10.7	1.8	15.3	2.6
5.8	13.1	2.2	18.6	3.2
5.6	15.3	2.7	21.9	3.8
5.4	17.6	3.1	25.2	4.4

[1] Ag ground limestone or dolomitic lime if the soil is low in both calcium and magnesium.
[2] If present pH is less than the desired level, add amount shown above.
[3] Buffer pH measures total soil acidity (H^+ & Al^{+++}) while pH measures H^+ only.

SUMMARY

Information on the nutrient content of soil is of value only when the soil is properly sampled, accurately analyzed and the results correctly interpreted. This report attempts to provide guidelines for interpreting soil analysis results and suggests nutrient sources and rates to correct an imbalance or deficiency of a nutrient.

FIELD FERTILIZATION PRACTICES

DICK AMMON

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Soils in the Cincinnati area are not ideal for agriculture. They are a clay loam top soil, which is rather shallow, with a heavy clay subsoil that is very slow to percolate. Nurseries in our area are much delayed for spring digging because of the wet soil. Our nursery is located on the highest point in our county. It is slightly rolling ridge land, and still drainage is a problem. The fertility of the soil is poor, and unless we apply ample fertilizer, the nutrients are not there. Now, with all this against our soils, we do find some bright sides. We have no rock until we get 9 feet deep and, if the nursery business is not profitable, the land is very valuable for development! Our biggest claim to fame is that we can successfully transplant trees even in the summer months. We contribute this to the