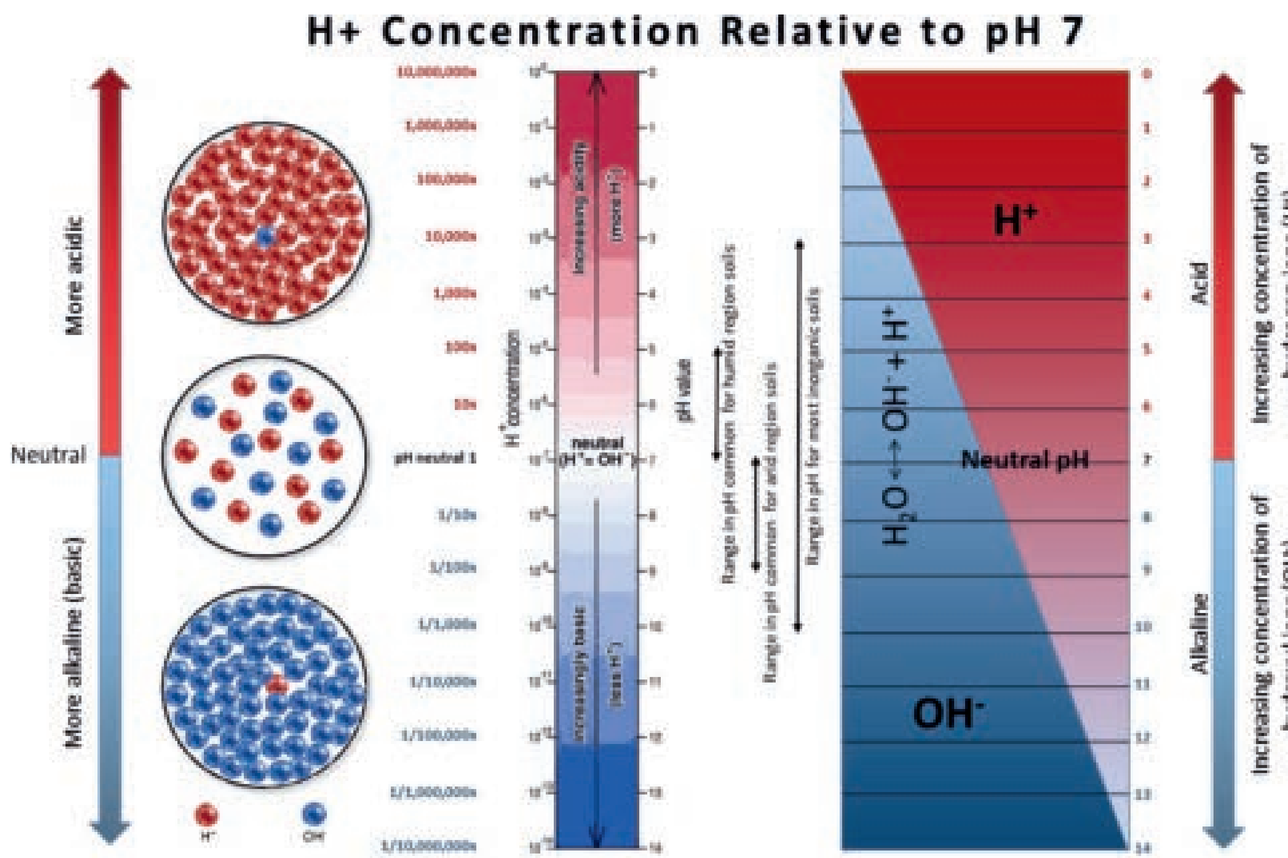
frequently and in smaller doses, particularly nitrogen and potassium that leach easily. Soil CEC can be greatly increased through the addition of organic matter. Soil organic matter has a large number of available bonding sites that hold nutrients and allow them to be released slowly over time. The risk of losing nutrients to groundwater is reduced when soil CEC is increased.

Soil Reaction (pH)

Soil reaction refers to the acidity or alkalinity of the soil and is a measure of the percentage of hydrogen ion (H^+) concentration. Soil reaction is measured as ***pH*** on a numerical scale that ranges from 0 to 14. Distilled or deionized water theoretically has a pH of 7 which is considered ***neutral***. A pH below 7 is considered ***acidic***; pH values greater than 7 are considered basic or ***alkaline***. The concentration of H^+ on the pH scale increases or decreases exponentially (by a power of 10 or 10^x). Therefore, a soil with a pH value of 5 is 10 (10^1) times more acidic than a soil with a pH value of 6 and 10 x 10 (10^2) or 100 times more acidic than a soil with a pH value of 7.

pH has a distinct effect on the availability of essential nutrients. Consequently, soil pH will affect the growth and quality of landscape plants. It does so by influencing both the chemical form of many elements in the soil and the soil microbial processes. Thus, landscape plants may exhibit nutrient deficiency or toxicity symptoms as a result of soil pH outside the optimum range.

The median pH for Florida soils is 6.1, which is characterized as slightly acidic. However, the pH of Florida soils can vary widely depending on the material from which the soil has formed. For example, well drained sandy soils that formed



graphic by gale allbritton

Figure 12. Diagrammatic representations illustrating the correlation between the relative concentration or percentages of hydrogen (H^+) ions to varying pH levels.

under pine flatwoods and organic soils can be quite acidic. In contrast, soils formed from materials high in calcium, such as limestone, marl, or sea shells, tend to be alkaline. This latter condition is common to coastal soils and the soils of south Florida. It is also common to encounter alkaline soils in the home landscape as a result of calcium-rich building materials (such as concrete, stucco, etc.) that may be left in the soil following construction. In general, alkaline soils are common in semiarid regions, while acid soils are more common in humid regions.

In acidic soils, the availability of plant nutrients such as potassium (K), calcium (Ca), and magnesium (Mg) is reduced, while the availability of potentially toxic elements such as aluminum (Al), iron (Fe) and zinc (Zn) are increased. In alkaline soils, iron (Fe), manganese (Mn), boron (B), zinc (Zn) and copper (Cu) are

Desirable pH Ranges for Common Ornamentals and Turf

Strongly Acid (pH ≤ 5.4)	Mod. to Strongly Acid (pH 5.5 – 5.9)	Moderately Acid (pH 6.0 – 6.4)	Slightly Acid (pH 6.5 – 7.0)	Slightly Alkaline (pH 7.1 – 7.8)	Moderately Alkaline (pH 7.9 – 8.4)
Woody Ornamentals					
aucuba	abelia	abelia	aucuba	agave	aucuba
azalea	allamanda	allamanda	bougainvillea	aucuba	black olive
blueberry	aucuba	aucuba	camellia	black olive	Geiger tree
bougainvillea	bougainvillea	bougainvillea	citrus	Geiger tree	gumbo limbo
crape myrtle	camellia	camellia	feijoa	gumbo limbo	oleander
gardenia	citrus	citrus	gardenia	live oak	palms
holly	crape myrtle	crape myrtle	Geiger tree	oleander	trumpet tree
hydrangea	croton	croton	hibiscus	palms	wax myrtle
ixora	feijoa	feijoa	hydrangea	plumbago	
ligustrum	gardenia	gardenia	live oak	podocarpus	
magnolia	hibiscus	hibiscus	oleander	satinleaf	
podocarpus	holly	holly	palms	southern red cedar	
yaupon	ligustrum	ligustrum	pittosporum	trumpet tree	
	magnolia	live oak	plumbago	wax myrtle	
	oleander	magnolia	podocarpus	yaupon	
	palms	oleander	satinleaf	yucca	
	pittosporum	palms	southern red cedar		
	plumbago	pittosporum	sycamore		
	podocarpus	plumbago	trumpet tree		
	trumpet tree	podocarpus	wax myrtle		
	yaupon	southern red cedar	yaupon		
		trumpet tree	yucca		
		yaupon			
		yucca			
Warm Season Turfgrasses					
bahia	bahia	bermuda	bermuda	St. Augustine	St. Augustine
centipede	centipede	St. Augustine	St. Augustine		
		zoysia	zoysia		

Figure 13. Examples of common plants adapted to varying ranges of pH.

commonly deficient. Furthermore, pH affects soil bacterial and fungal activity, enhancing or inhibiting the development of soilborne plant diseases, or influencing how efficiently they function as beneficial decomposing organisms. It is also important to be aware that many pesticides and liquid forms of fertilizer perform best with a water pH of 5.5 to 8. For that reason, it is important to test water as well as soil.

Fortunately, most common landscape plants are well suited to a wide range of soil pH. For example, popular woody shrubs and trees such as pittosporum, viburnum, oaks and pines will grow well in acid to moderately alkaline soils. In addition, several common lawn grasses can tolerate wide ranges in soil pH. The ***optimum pH range*** for most plants is between pH 5.5 and 7.0. However, there are a few acid loving plants, including azalea, blueberry, gardenia and ixora that do better in acid soils with a pH of 4.5 to 5.5.

Plant pH requirements are determined from scientific experimentation or extended observation; therefore, it is wrong to assume a particular species will grow best at pH 5.5 to 7.0 simply because most plants do best in that range. It is important to know the most desirable pH range for plants being grown in the landscape or in production in order to maintain optimum growth efficiency and health.

Soil Testing Procedures

A soil test provides information about the nutritional status of a soil and may aid in the detection of potential problems limiting plant growth. The chemical status of a soil cannot be measured visually; it should always be tested using appropriate equipment before adding amendments. A number of simple chemical tests are available and accurate enough for horticultural use, so measuring pH can be done easily. A wide variety of pH meters for more precise electrical testing are also available. To assure accuracy, work closely with the local University of Florida IFAS Extension Service on soil testing both for pH and nutrients.

To test soil in the landscape, a ***composite soil sample*** should be obtained by removing subsamples from 10 to 15 small holes randomly selected throughout the sample area (for example, the front yard). Carefully pull back mulch, grass or groundcovers to expose bare soil. With a trowel or shovel, dig small holes 6-inches deep and remove a 1-inch thick by 6-inch deep slice of soil from the side of each hole. Combine and mix the subsamples in a clean plastic bucket. The soil should be spread on a nonporous surface out of direct sunlight and allowed to dry thoroughly before testing. To obtain the most reliable results, take separate composite samples from areas that have different soil types, receive different cultural practices or contain plants that have distinctly different fertility requirements. Two to three areas from a quarter to 1-acre lot will often be sampled separately.

In container production, separate media samples should be collected from blocks where plants are treated and grown under similar conditions, such as media type, irrigation, container size, etc. Collect 5 to 20 subsamples from plants within the block using a soil probe. Samples should include media from the entire container profile (depth); the top layer should be removed to avoid inclusion of any fertilizer. Combine and mix media in a clean plastic

Figure 14. Inexpensive soil test meter for the field.

bucket and allow the composite sample to dry prior to submitting for testing.

Collected samples, accompanied by completed collection and submission forms, should be sent to a university or commercial laboratory for more extensive test results. Remember that sample collection of landscape soil should precede spring fertilization by a couple of months in order to allow time for adjustments in pH if needed. Container media should be sampled more often to coincide with production schedules.

Sample collection and submission forms for soil testing are available from the local University of Florida IFAS Extension office or the UF/IFAS Extension Soil Testing Laboratory. UF publications Container Media Test Information Sheet SL-134, Producer Soil Test Information Sheet SL-135, or Landscape and Vegetable Garden Test Information Sheet SL-136 should be referenced for additional information.

Adjusting the pH of Landscape Soils

The best advice regarding soil pH is to choose landscape plants suited for the naturally occurring pH of the landscape soil. While there are soil additives that can raise or lower soil pH, the effect of these materials is often very short-lived; plus adjusting pH will probably not improve plant performance if the soil pH is within 0.4 of a pH unit of the ideal range.

Raising pH

To raise the pH of acidic soils, add a liming material like calcium carbonate or dolomite. The amount of lime application to acid soils depends largely on the initial pH and the ***buffering capacity*** (ability to resist a change in pH) of the individual soil. The Soil Testing Laboratory at UF uses a method that considers pH and buffering capacity in determining the lime requirement of individual soils. Much of the difference in buffering capacity of individual soils is related to the amount of silt, clay and organic matter present. The greater the amounts of these materials present, the higher the buffering capacity.

Crushed agricultural limestone or ***dolomite*** are the liming materials typically used to raise soil pH. Because magnesium is often deficient in Florida soils, dolomite is preferable in most locations in Florida since it contains magnesium (Mg) as well as calcium carbonate ($CaCO_3$). ***Hydrated lime*** (calcium hydroxide or $Ca(OH)_2$) may also be used to raise pH; however, the amount should be reduced by 25% because hydrated lime reacts much more quickly and can burn plants more easily than carbonate lime.

In order for lime to be effective, it should be thoroughly mixed into the top six (6) inches of the soil. This is easily accomplished before planting a garden or landscape. When applying lime to established landscapes or turf, incorporation techniques can damage plant roots. In this case, lime should be surface applied and watered in.

Overliming or adding lime when the soil does not need it can have negative effects that can be worse than doing nothing. An approximation of the amount of agricultural or dolomitic lime needed for raising pH can be made using the *Landscape (Field) Soil pH Adjustment* table on the next page.

Figure 15. Granular dolemitic lime for raising pH.

Figure 16. Sulfur in powder form for lowering pH.

Lowering pH

Lowering the pH to acidify the soil may be desirable in some situations. However, unlike liming, lowering the pH of strongly alkaline soils is much more difficult. In fact, there is no way to permanently lower the pH of soils formed from high calcium materials such as marl or limestone, or soils severely impacted by alkaline materials used in the construction of a roadbase, fill, or foundation. Treatment with sulfur will lower the pH for a few weeks, but the pH will eventually increase.

Adding any acidifier to soils composed of high calcium materials will only temporarily adjust the pH because the acidification causes the limestone or shell to become soluble, which then neutralizes the acidifier. In landscaping, it is often better to select plants adapted to high pH conditions, rather than use plants that will need constant soil pH maintenance. If this approach is not taken, plants will have continuing nutritional problems and usually look unhealthy even after the extra effort to lower pH. To avoid artificially creating this situation, decorative limestone rocks should not be used in the landscape. Other rocks, such as river gravel, are less soluble and have little effect on pH. In contrast, if a high pH is the result of overliming, correction may be possible.

If adjustment is desired, the soil pH can be lowered by adding ***elemental sulfur***. ***Super-fine wettable*** or ***dusting sulfur*** is also used to lower soil pH. The rate for dusting sulfur needed to decrease the soil pH one unit is approximately one-third (1/3) of the amount of limestone used to raise the soil pH one unit. The amount applied should not exceed one (1) pound per 100 square feet at any one application. If sulfur is being applied around living plants, the same amount should be applied; however, two separate applications should be made 60 days apart. The *Landscape (Field) Soil pH Adjustment* table below indicates rates for lime applications, but can be used to calculate the amount of sulfur needed to make pH adjustments; however, remember

Landscape (Field) Soil pH Adjustment
Agricultural Limestone or Dolomitic Limestone to Increase pH One (1) Unit

Soil of ***Low*** Organic Matter Content Indicated in Pounds of Limestone per Unit					
Soil Texture	**10 sq ft**	**100 sq ft**	**1,000 sq ft**	**4 cu ft**	**1 cu yd**
Sand	0.4	3.7	37	0.3	2.0
Loamy sands	0.5	4.7	47	0.4	2.5
Sandy loams	0.6	6.0	60	0.5	3.25
Sandy clay loams	0.9	9.3	93	0.75	5.0
Soil of ***Moderate*** Organic Matter Content Indicated in Pounds of Limestone per Unit					
Soil Texture	**10 sq ft**	**100 sq ft**	**1,000 sq ft**	**4 cu ft**	**1 cu yd**
Sand	0.4	7.0	70	0.6	3.8
Loamy sands	0.8	8.4	84	0.7	4.5
Sandy loams	0.9	9.3	93	0.75	5.0
Sandy clay loams	1.1	10.9	109	0.9	5.9

***NOTE**: To calculate the rate of sulfur needed to lower pH one (1) pH unit, use one-third (1/3) the rate of the figures represented above.*

Figure 17. Recommended rates of amendments required to adjust pH of various soil textures.

photo by gale allbritton

Figure 18. An appropriate plant for site conditions should be selected to replace this lady palm suffering from iron deficiency growing in a calcareous (high pH) soil.

to use only one-third (1/3) the total amount. Make sure to monitor plants carefully after sulfur application.

Other sulfate containing materials (ammonium sulfate, iron sulfate, aluminum sulfate) can also be used to lower the soil pH. These are often included in so-called ***acid-forming fertilizers*** commonly applied to azaleas and camellias. However, be aware that not all sulfate materials, such as calcium sulfate (gypsum), magnesium sulfate (Epsom salt), or potassium sulfate will acidify soil. Alternatively, organic materials such as peat or manure also reverse the effects of alkaline soil pH on some landscape plants. Since these materials decompose with time, annual or semiannual applications are usually required.

Iron sulfate (ferrous sulfate) can likewise be used to lower soil pH, with a faster but more temporary effect than wettable sulfur. Iron sulfate helps add iron, which is often unavailable with high pH. However, it is relatively expensive, and will stain sidewalks. If used, the standard rate for iron sulfate is one (1) pound per 100 square feet. It may be necessary to reapply in 60 days, but repeated applications may reduce the amount of manganese (Mn) available in the soil. Aluminum sulfate is also effective in correcting pH, but too much aluminum can be harmful to plant growth.

Adjusting pH of Soilless Mixes

Because of the relationship between pH and nutrient availability, maintaining the correct pH in nursery and greenhouse potting mixes (soilless media) is crucial to successful production of plants. Most foliage and woody plant crops grown in the nursery or greenhouse tolerate a more acid potting mix than landscape soil; this is because the level of aluminum in soilless media is generally too low to cause problems. Container grown foliage crops perform well between pH 4.5 and 6.5 and container grown woody plants do well between pH 5.0 and 6.5. Changing the pH after plants are potted and growing is difficult. Therefore, adjustments are most easily made prior to planting.

Before Potting

Low pH levels can be raised in potting media by adding liming materials, such as ***dolomite*** or ***calcium carbonate***; high pH levels are lowered by adding ***sulfur***. The amounts of these materials needed to provide a desired pH depends on the type of organic material in the potting mix and the original pH. The materials must be carefully measured and thoroughly mixed into the media before planting.

In sandy potting media, small amounts of lime or sulfur are needed, while larger amounts are required to affect the pH of pure peat because of its higher buffering capacity. The *Container Media pH Adjustment* table (next page) serves as a guide for adjusting pH levels during potting media preparation. The table indicates modifications needed to achieve a desirable pH of 5.7 for container grown crops.

After Potting

To raise the pH of a potting mix after crops are already growing, ***hydrated lime*** (calcium hydroxide or $Ca(OH)_2$) should be used, but with caution. Hydrated lime can damage plants if applied in solution at more than one (1) pound per 100 gallons per 100 square feet of surface area (pots or benches). The crop may need to be treated again four weeks later if pH has not reached the desired level. ***Calcium carbonate*** (lime), applied to the surface of the potting mix and watered in, will also raise pH. However, it may take longer for it to be effective.

If pH levels are too high in potting mixes of established crops, ***sulfur*** can be applied at the rate of 1 pound per 100 square feet of surface area to lower pH. Sulfur should not be applied more often than every four weeks because rapid pH changes may damage plants. The use of fertilizers that have a high ***acid forming potential*** (calcium nitrate, ammonium-based nitrogen, phosphoric acid, iron sulfate) can also be one of the tools chosen to help lower or maintain a lower pH in potting mixes. The acid forming potential or the acid neutralizing effect of a fertilizer is expressed in ***calcium carbonate equivalents (CCE)*** per unit weight of fertilizer. Essentially, CCE represents the pounds of calcium carbonate (limestone) it takes to neutralize one ton of a fertilizer or fertilizer component. The higher the number, the greater the acid forming potential of the fertilizer. These fertilizers should also be used cautiously to avoid plant damage.

As we have seen, there are several means available to adjust container medium pH. The specific method chosen will depend on whether or not there is a need for a quick fix or if a gradual method to control pH over time can be considered. Fertilizer management strategies, irrigation water pH, and buffering capacity of media components must also be taken into account.

Alternatives to Correcting pH

1) Select plants tolerant of existing soil pH. This is a step toward low maintenance landscaping.
2) Use a fertilizer program designed to overcome specific nutrient problems. This alternative requires considerable expertise, and may involve regular use of soil acidifiers, chelated fertilizers and foliar applications of plant nutrients.
3) Remove and replace enough soil in the planting holes to allow the plant to grow in an "island" of good soil. This method can be expensive and must be done at planting.
4) Regularly apply organic mulch to the soil surface, so that the organic content of the soil gradually increases, which gradually reduces the pH.

Container Media pH Adjustment ***The approximate amount of lime and sulfur required to adjust pH of potting mixtures***			
Dolomitic lime (pounds per cubic yard) or equivalent amount of calcium to ***raise pH*** of indicated media to 5.7			
Beginning pH	**50% Peat + 50% Sand**	**50% Peat + 50% Bark**	**100% Peat**
5.0	1.7	2.5	3.5
4.5	3.7	5.6	7.4
4.0	5.7	7.9	11.5*
3.5	7.8	10.5	15.5*
Sulfur (pounds per cubic yard) to ***lower pH*** of indicated media to 5.7			
Beginning pH	**50% Peat + 50% Sand**	**50% Peat + 50% Bark**	**100% Peat**
7.5	1.7	2.0	3.4
7.0	1.2	1.5	2.5
6.5	0.8	1.0	2.0
*Addition of more than 10 pounds of dolomite per cubic yard often causes micronutrient deficiencies. *(Adapted from Light and Fertilizer Recommendations for Potted Foliage Plants, by Charles Conover and R.T. Poole, Agricultural Research and Education Center, Apopka, FL)*			

Figure 19. Recommended rates of amendments required to adjust pH of various potting soil mixtures.