Greenhouse Growth Media: Testing and Nutrition Guidelines
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Greenhouse Growth Media: Testing & Nutrition Guidelines

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Greenhouse growth media have chemical and physical properties which are distinctly different from field soils. Over the past 10 to 15 years, greenhouse operators have changed from using mixes containing soils to peat or bark-based mixes containing other manufactured materials such as perlite, vermiculite and expanded polystyrene beads. The "soilless" growth media have good moisture holding and aeration properties, but limited nutrient holding capacities. As a result, fertility management in the greenhouse is more important than ever before.

Being knowledgeable about physical and chemical properties is a prerequisite for good management. An analysis of a growth medium[1] provides basic information on which to build a fertility program. Prior to using any new lot of growth medium, test for pH, soluble salt content and available nutrient levels. Even though most companies maintain quality control programs, variations in growth media properties do occur. Knowing the initial chemical properties is essential to avoiding costly plant growth problems later. The Michigan State University Soil Testing Lab offers a testing program specifically designed for analyzing "soilless" growth media used in producing greenhouse crops.[2]

In "soilless" greenhouse growth media, the concentration of essential nutrients around the root is critical to plant growth and depends upon the moisture holding capacity (MHC) of the medium. With a given amount of nutrient in a container of growth medium, the nutrient concentration around the root decreases as the moisture content increases. Since growth media vary widely in bulk density (weight per unit volume) it has been difficult to develop a single set of fertilization guidelines.

Table 1. General information guidelines for greenhouse growth media analyzed by the Saturated Media Extract (SME) method.

Analysis	*CATEGORY*				
	Low	*Acceptable*	*Optimum*	*High*	*Very High*
Soluble Salt, mS/cm	0-.75	.75-2.0	2.0-3.5	3.5-5.0	5.0+
Nitrate-N, ppm	0-39	40-99	100-199	200-299	300+
Phosphorus, ppm	0-2	3-5	6-9	11-18	19+
Potassium, ppm	0-59	60-149	150-249	250-349	350+
Calcium, ppm	0-79	80-199	200+	-	-
Magnesium, ppm	0-29	30-69	70+	-	-

With the saturated media extract procedure, it is possible to use a single set of fertilization guidelines (Table 1) since the amount of water held at saturation is directly related to the moisture holding characteristics of each medium. At complete saturation, the water content of a medium is approximately four times that held at the permanent wilting point (PWP) and about two times that held against gravity (MHC). The total soluble nutrient concentration at saturation is therefore one-fourth that at the PWP and one-half that at MHC.

Desirable pH, soluble salt and nutrient levels vary with the greenhouse crop being grown and management practices. General guidelines for the most important fertility parameters are given in Table 1. Acceptable sodium and chloride levels depend upon the total soluble salt content.

To obtain maximum crop growth, adjust the media to optimum nutrient levels before planting. Consider the following when adjusting growth media nutrient levels.

[1] *Growth medium or media refer to any material(s) in which plants are grown.*

[2] *Greenhouse growth media are analyzed using a saturated media extract (SME) procedure. Approximately 400 cc of a growth medium is mixed with sufficient distilled water to just saturate the medium. pH is determined on the saturated mix. After one hour, the saturation solution is removed with a vacuum filter. All subsequent analyses are performed on the extracted solution.*

pH - Growth media pH influences the availability and plant uptake of all essential plant nutrients. In peat based media, the most desirable pH is 5.6 to 5.8 for most plants. Most irrigation waters in Michigan are alkaline, above pH 7.0. Watering plants with alkaline water will gradually raise the growth medium pH; over a three month period, the pH may increase 0.5 to 1.0 pH unit. Thus, it is extremely important for the growth medium pH to be properly adjusted prior to planting. Too high a pH, greater than 6.5, increases the chances of micronutrient deficiencies. Too low a pH, less than 5.3, may result in calcium and/or magnesium deficiency or manganese toxicity.

The amount of lime to add for pH adjustment depends on the buffering (ability to resist change) capacity of the growth medium. To bring about a one pH unit change (e.g., 4.5 to 5.5) in weakly buffered growth media may require only 2 lb of finely ground lime per cubic yard, whereas 5 lb per cubic yard may be required in a more highly buffered growth medium. Amendments such as perlite, expanded polystyrene beads, and expanded vermiculite have little or no buffering capacity. Fibrous peat and shredded bark or wood also have limited buffering ability. Somewhat decomposed peat, muck, well composted bark and field soil provide a higher degree of buffering.

When adding lime to a greenhouse growth media, remember that it is better to under lime initially than to over lime. Mix up a small batch (0.1 cubic yard) of growth medium using the lime rate judged to be correct. Moisten the medium as you would before planting and place in a large plastic bag for two weeks, then sample and check the pH. If the pH is between 5.5 and 6.0 the lime rate is acceptable. If the pH is outside this range adjust the rate accordingly. Always use finely ground lime passing through a 100 mesh sieve. Coarser liming materials such as agricultural lime may take up to 6 months to fully react and bring about the desired pH change. Lime will not react in dry stockpiled growth media; but when the growth medium is moist, fine lime will fully react within two weeks. Calcitic lime supplies only calcium whereas dolomitic lime contains both calcium and magnesium.

Avoid growth media with too high a pH because lowering the pH is more difficult than raising it. High pH growth media can be acidified by mixing in iron sulfate. Approximately a one pH unit decrease (e.g., pH 7.5 to 6.5) can be brought about with 3 lb iron sulfate per cubic yard. The exact change will depend on the buffering nature of the mix components.

Adjusting the pH in pots, benches or flats with growing plants present is more difficult and may cause plant injury. Limewater can be used to neutralize acid growth conditions (raise the pH). Adjustment is not suggested if the pH is 5.4 or above. Stir one pound of finely ground lime into 100 gallons of water, let settle overnight and apply the clear solution, avoiding or filtering out any settlings. The growth medium should be quite moist at the time of application to minimize root shock and injury. Avoid getting the solution on the foliage or wash off the foliage immediately after application. *Do not apply ammonium containing fertilizer immediately before or after a limewater application. Ammonium reacts with lime to release volatile ammonia which may burn plant foliage.*

Alkaline irrigation water can be acidified using phosphoric, nitric or some other acid. The amount of acid to use depends on the pH of the water and its hardness. As a starting point, one ounce of 85% phosphoric acid or two ounces of 70% nitric acid added to 100 gallons water will cause a pH change of 1.0 to 1.5 units (e.g., 7.8 to 6.8 or 6.3). Precise adjustment will require some trial additions and monitoring of the resulting water pH. Injecting acid into the irrigation system also cleans out the irrigation lines and spray or drip nozzles. *Exercise extreme caution when using acid. Keep sodium bicarbonate on hand to neutralize any acid spills.*

SOLUBLE SALTS - All soluble ions or nutrients such as nitrate, ammonium, potassium, calcium, magnesium, chloride and sulfate contribute to the soluble salt content of a growth medium or water. Total soluble salt content in water or a growth medium extract is determined with a solu-bridge (conductivity meter) and expressed in millisiemens[3]. To convert this value to ppm (parts per million) multiply by 700 (700 x millisiemens per cm = ppm),

Greenhouse operators commonly use a one part growth medium to two parts distilled water (volume: volume basis) to determine soluble salt content. A 1:5 ratio may be used if more solution is needed. The MSU Soil Testing Lab determines soluble salt content on the saturation extract. Guidelines for interpreting soluble salt levels by each procedure are given in Table 2. Mixing fertilizer into a growth medium will increase the soluble salt content. In general, each pound of soluble fertilizer mixed in per cubic yard will increase the soluble salt content in the saturation extract 1.0 mS per cm. The exact increase will depend on the fertilizer used.

Soluble salt buildup can be minimized by watering to cause some leaching. Excessively high soluble salt levels can be reduced by leaching the soluble salt content down to an acceptable level. Watering the container or bed so a good amount of water drains out and then repeating this procedure one to two hours later will reduce the soluble salt level sufficiently. Extremely high soluble salt levels may require repeating the procedure two or three days after the first.

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[3] *Millisiemen (mS) replaces millimho (mmho) as the preferred unit for expressing conductivity (soluble salt) measurements. The value remains the same — only the name changes.*

Table 2. Soluble salt guidelines for greenhouse growth media using various media to water ratios.

SOLU-BRIDGE READING			
*Saturation Extract**	*1 part media to 2 parts water*	*1 part media to 5 parts water*	*Comments*
mS			
0-.74	0-.25	0-.12	Very low salt levels. Indicates very low nutrient status.
.75-1.99	.25-.75	.12-.35	Suitable range for seedlings and salt-sensitive plants.
2.00-3.49	.75-1.25	.35-.65	Desirable range for most established plants. Upper range may reduce growth of some sensitive plants.
3.50-5.00	1.25-1.75	.65-.90	Slightly higher than desirable. Loss of vigor in upper range. OK for high-nutrient-requiring plants.
5.00-6.00	1.75-2.25	.90-1.10	Reduced growth and vigor. Wilting and marginal leaf burn.
6.00 +	2.25 +	1.10 +	Severe salt injury symptoms with crop failure likely.

*Used by the Soil Testing Lab at Michigan State University

NITRATE-NITROGEN - Plants deficient in nitrogen become light green in color beginning with the older leaves. Some nitrogen deficient plants may also exhibit a reddish coloration. Nitrogen is an important component of the chlorophyll molecule. The nitrate form of nitrogen is soluble and mobile in the growth medium so with watering some of the nitrate may leach out.

Optimum nitrate-N levels vary with plant-age and type. Some guidelines are given in Table 3. Young plants and seedlings do best with low to medium nitrate levels. Most pot and bedding plants in a "growing on" stage require moderately high levels. Crops grown in ground or raised beds do well with high nitrate levels. The initial level of nitrate-N can be adjusted in a stock growth medium using the guidelines given in Table 4.

A fairly constant level of available nitrogen can be maintained by injecting additional nitrogen into the watering system. When injecting fertilizer into the irrigation water, be sure to water adequately to cause some leaching and prevent excess nitrate and soluble salt buildup.

PHOSPHORUS (P) - An adequate phosphorus supply is important for root system development, rapid growth and flower quality in floral plants. Phosphorus-deficient plants exhibit slow root and top growth. In severe cases, the foliage will exhibit a purplish coloration. Phosphorus plays an important role in the photosynthetic process. Phosphorus compounds (being only slowly soluble) are generally subject to limited leaching loss, but leaching may be significant (up to 30%) in fibrous, peat-lite mixes. Sufficient superphosphate can be mixed initially into a growth medium (mix) to supply phosphorus throughout the growth period without concern for undue leaching loss or soluble salt buildup.

Crops grown in ground or raised beds require higher phosphorus levels than pot or bedding plants (Table 5). Plants grown at cool temperatures sometimes develop phosphorus deficiencies, even with adequate phosphorus present. This is due to limited root growth and activity.

Table 3. Desirable nitrate-nitrogen concentrations in a greenhouse growth medium saturation extract.

	ppm NO_3-N in extract
Seedlings	40-70
Young pot and foliage plants	50-90
Pot and bedding plants — growing on	80-160
Roses, mums, snapdragons in ground or raised beds	120-200
Lettuce and tomatoes in ground beds	125-225
Celery transplants	75-125

Table 4. Nitrogen fertilizer needed to increase the nitrate level in the saturation extract 10 ppm N.

Nitrogen Carrier	*N Content*	*To increase test level 10 ppm, use:*		
	%	oz/bu	oz/cu yd	oz/100 sq ft
Potassium Nitrate	13	0.12	2.3	4.6
Calcium Nitrate	15	0.10	2.0	4.0
Ammonium Nitrate	33	0.45	0.9	1.8
Urea	45	0.35	0.7	1.4

Table 5. Desirable phosphorus concentrations in greenhouse growth media saturation extracts.

	ppm P in extract
Seedlings	5-9
Bedding and pot plants	6-10
Lettuce and tomatoes in ground beds	10-15
Roses, mums, snapdragons in ground or raised beds	10-15
Azaleas	7-12
Celery transplants	10-15

Table 6. Phosphorus fertilizer needed to increase the phosphorus level in the saturation extract 2 ppm P.

Phosphorus Carrier	*P_2O_5 Content*	*To increase test level 2 ppm, use:*		
	%	oz/bu	lb/cu yd	lb/100 sq ft
Normal superphosphate	20	0.75	.90	1.8
Concentrated superphosphate	46	0.33	.40	0.8
Bone Meal	25	0.60	.75	1.5

Raising the temperature 5°F will enable the plants to grow out of this condition more easily than will the addition of more phosphorus.

Concentrated superphosphate (0-46-0) is the phosphorus source most available to greenhouse operators, however, normal superphosphate (0-20-0) is better for use in greenhouses because it contains extra calcium and sulfur. Table 6 provides guidelines for increasing the available phosphorus levels in most greenhouse growth media. Mixes containing greater than 25% calcined clay or muck will require about 2.5 times more phosphate fertilizer to achieve the same increase in extractable phosphorus. Do not use superphosphate for lilies because of potential flouride toxicity. Flouride is contained in rock phosphate — the base material used for production of superphosphate. Bone meal is a better phosphorus source for lilies.

Care should be taken not to over fertilize with phosphate. Excessively high phosphate levels may reduce the ability of plants to take up and utilize several of the micronutrients. If the irrigation water pH is being adjusted with phosphoric acid, additional phosphorus probably is not necessary. Each ounce of 85% phosphoric acid added per 100 gallons of water supplies 83 ppm P_2O_5 (36 ppm P). The percent phosphate listed on the fertilizer label is as percent P_2O_5, and P_2O_5 contains only 43 percent actual P.

POTASSIUM (K) - The nutrient most often limiting in greenhouse fertility programs is potassium. The lower or oldest leaves of K deficient plants show marginal yellowing or chlorosis. Spotting over the entire leaf is sometimes also associated with K deficiency. Many greenhouse plants have a K requirement equal to or greater than their nitrogen requirement. As a result, K levels are depleted more readily than N levels. Potassium salts are water soluble and leachable in soilless growth media with low nutrient holding capacities. Soluble fertilizers are commonly injected into the watering system to supply 200 ppm nitrogen and many of these fertilizers (such as 20-20-20 or 25-0-25) contain equal amounts of N and K_2O. However, K_2O is only 83% K and plants are receiving only 166 ppm K in the fertilizer solution.

Table 7. Desirable potassium concentrations in greenhouse growth media saturation extracts.

	ppm K in extract
Seedlings	100-175
Bedding plants	150-225
Pot plants	175-250
Lettuce and tomatoes in ground beds	200-300
Roses, mums, snapdragons in ground or raised beds	200-275
Azaleas	125-200
Celery	250-300

Table 8. Potassium fertilizer needed to increase the potassium level in the saturation extract 25 ppm.

Potassium Carrier	*K_2O Content*	*To increase test level 25 ppm, use:*		
		oz/bu	oz/cu yd	lb/100 sq ft
Potassium nitrate	44	0.19	3.75	0.46
Potassium sulfate	50	0.16	3.25	0.40
20-20-20	20	0.41	8.25	1.03

The demand for K is greatest in rapidly growing plants in the vegetative stage. Seedlings and young plants usually do better with a low to medium K level. Optimum K levels are given in Table 7 for various categories of plants.

Potassium nitrate has a K:N ratio of about three to one and is ideal for building up the potassium content of a growth medium. Since both the potassium and nitrate portions of the salt are utilized by plants, concern over soluble salt buildup is less than with other potassium sources. Establishing a near optimum K level in the growth medium before planting is desirable to insure a more consistent K supply throughout the growth period. The quantities of potassium fertilizer to obtain the necessary buildup are given in Table 8.

Potassium sulfate is a suitable K source but is not very soluble. Potassium chloride is not recommended for greenhouse use because of its high salt index.

CALCIUM (Ca) - Availability of calcium for plant uptake is dependent on pH of the growth media and levels of other cations present, especially potassium and magnesium. Calcium deficiency in plants results in abnormal growth or death of the growing tip. As a growth medium becomes more acid (lower pH), especially below pH 5.0, Ca becomes less available.

Available Ca levels may be marginal in "soilless" greenhouse media, especially those having an acid peat as the base material, unless amended with lime. To effectively change the pH and available Ca level, lime must be thoroughly mixed in and the growth medium must be adequately moist. Many of the Ca carriers are slowly soluble so that equilibrium will not be reached if the stockpiled growth media are maintained dry. As a result, the Ca content in a saturation extract may not accurately reflect the available Ca content of the growth media.

Calcium levels can be increased by adding lime to acid growth media. Calcium sulfate (gypsum) and calcium nitrate can be used to add Ca to growth media not needing pH adjustment. Appropriate quantities to add are given in Table 9. Calcium sulfate is insoluble and does not water in well, but calcium nitrate is soluble and can be watered in.

Table 9. Calcium carriers to increase the calcium level in the saturation extract 25 ppm.

Calcium Carrier	*Ca Content*	*To increase test level 25 ppm, use:*		
	%	oz/bu	oz/cu yd	lb/100 sq ft
Calcitic lime	30-34	0.21	4.2	0.53
Dolomitic lime	20-24	0.30	6.0	0.75
Calcium sulfate	23	0.29	5.8	0.73
Calcium nitrate	19	0.35	7.0	0.88
Normal superphosphate	20	0.33	6.7	0.84
Concentrated superphosphate	13	0.51	10.2	1.28

MAGNESIUM (Mg) - Reactions of magnesium in growth media are similar to calcium. Lower leaves of magnesium-deficient plants exhibit an interveinal chlorosis. This chlorosis may sometimes also appear on the upper leaves as well. Some soilless mixes are low in available Mg unless the pH has been adjusted with dolomitic lime. Growth media containing vermiculite usually have adequate Mg levels since vermiculite naturally contains Mg. Low Mg levels in acid mixes can be corrected by addition of finely ground dolomitic lime. Magnesium sulfate (Epsom salts) at 4-8 ounces per cubic yard or per 100 gallons (for drenching) is the best material to use in growth media not requiring lime. *When injecting magnesium sulfate into the watering system, do not mix it with any other material unless you are sure it does not contain calcium or phosphorus. Several injectors have been plugged by precipitates formed when magnesium sulfate was injected with a calcium and/or phosphorus containing fertilizer.*

Table 10. Desirable nutrient balance in saturation extract.

Nutrient	*% of Total Soluble Salt*
Nitrate-N	8-10
Ammonium-N	less than 3
Potassium	11-13
Calcium	14-16
Magnesium	4-6
Sodium	less than 10
Chloride	less than 10

NUTRIENT BALANCE - Potassium, calcium and magnesium compete for similar uptake sites at plant root surfaces. Increasing the concentration of one relative to the others will change their relative availability. Similarly, a high sodium (Na) level may depress the uptake of K, Ca or Mg. Hence, the balance among the essential plant nutrients, especially K, Ca and Mg, is important.

When expressed as a percent of total soluble salts, the nutrient balance given in Table 10 has been found to give the best plant growth. Although the situation given in Table 10 is the most desirable, having the nutrients present at other levels, but in the same proportions as in Table 10, may also represent a nutritionally balanced growth medium. Plant growth is better with balanced nutrient levels even at low fertility. High soluble salt levels are better tolerated by plants in a balanced nutrient situation.

Table 11. Suggested general mirconutrient formulation to mix into stock growth media.

Compound	*Quantity to use per cubic yard:*
Iron chelate (6% iron)	1.0 oz
Manganous sulfate	1.0 oz
Copper sulfate	0.3 oz
Zinc sulfate	0.2 oz
Sodium borate (borax)	0.1 oz
Sodium molydbate	0.03 oz

MICRONUTRIENTS - Micronutrients are essential nutrients required in small quantities. Many artifical mixes, especially peat based ones, may be deficient in micronutrients unless appropriate amendments are added. For these mixes, it is essential to add a complete micronutrient mix, 3-4 oz/cu yd (Table 11). This can be done either by the commercial manufacturer or the grower.

All essential micronutrients, except molybdenum, become less available as the pH increases. Hence, to prevent micronutrient deficiencies, it is important to maintain the pH below 6.0 as well as to add micronutrients.

Iron (Fe) and manganese (Mn) are the two micronutrients most likely to be deficient, especially at pH's above 6.5. Total yellowing of the youngest immature leaves is a good indicator of Fe deficiency, whereas mottling or striping of the youngest fully developed leaves may indicate Mn deficiency. For correction of an Fe deficiency use 4 ounces of an iron chelate per 100 gallons water. Iron sulfate can be used but is less soluble and less effective in correcting an existing deficiency. Especially with alkaline conditions (pH above 7.0) iron from iron sulfate becomes tied up, whereas iron in the chelate form remains available.

For correcting an Mn deficiency, either manganese sulfate at 1- 2oz/100 gal or a manganese chelate at 4-8 oz/100 gal is effective. *Never use a manganese chelate in conjunction with iron sulfate.* The other combinations of iron and manganese carriers are compatible.

Copper (Cu) and zinc (Zn) deficiencies occur infrequently. Both sulfate and chelate forms of these nutrients are effective. Use 1 oz/100 gal for the sulfate form and ¼ oz/100 gal for the chelate form.

Extreme care must be exercised when applying boron (B) as the difference between deficiency and toxicity is very small. Uniform application is very important and is best done as a liquid solution. Use no more than ¼ oz borax (11% B) per cubic yard or per 100 gallons water on a one time basis. Boron in the irrigation water is a potential source of B toxicity. Levels greater than 0.5 ppm may result in injury to sensitive crops. Know the quality of your irrigation water.

Molybdenum (Mo) deficiency is seldom seen, but may occur when the growth medium is quite acid, near pH 5.0 or below. Poinsettias are more likely to develop molybdenum deficiency than other ornamentals. The quantity required is so small that uniform application can only be attained with a liquid solution.

The presence of flouride (F) may adversely affect the quality of lilies and some foliage plants. More than 5 ppm F in the saturation extract of a growth medium is likely to result in some type of flouride injury for sensitive plants. Excess F may cause some tip burn and marginal chlorosis. Adding Ca as lime or calcium sulfate (5 lb/cu yd) will "fix" the F in an unavailable form and usually eliminate the adverse F effect.

SLOW-RELEASE FERTILIZERS - These carriers need to be used with understanding. The two primary materials being used are MagAmp and Osmocote. MagAmp (7-40-6 plus 8% Mg) is pelletized and slowly dissolves. MagAmp serves primarily as a source of P and Mg. All of the nitrogen is in the ammonium form. Many growers using MagAmp fail to supplement adequate potassium. MagAmp may be added to growth media prior to steaming since steaming has little effect on the dissolution rate.

Osmocote fertilizers are resin-coated. Fertilizer release depends on water vapor moving in and dissolving the fertilizer. As more water moves in, the dissolved fertilizer is "squeezed" out. Steam sterilization of growth media containing Osmocote will result in accelerated fertilizer release and high soluble salt levels. Add Osmocote fertilizer *after* steam sterilization. Several analyses of Osmocote fertilizer are available. Select one based on test information which will provide a balanced fertility program.

Rates for use of MagAmp and Osmocote fertilizer are 8-10 pounds per cubic yard. When additional fertilizer is injected through the watering system, one-half the above rate is suggested.

Some testing methods result in inflated test results for growth media containing slow release fertilizers. The saturated media extract (SME) method used by the Michigan State University Soil Testing Lab has very little effect on increasing the solubilization of slow release fertilizers. Therefore, the SME method reflects well the available nutrient situation in which the plant roots will be growing.

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