Bedding Plant Fertilization Strategies

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In the August 1995 issue of the Bulletin (Volume 40, Number 4 p. 3–8), we outlined the physical properties of greenhouse substrates that growers should be aware of prior to substrate purchases or substrate blending. You may wish to refer back to this article to refresh your memory for the ongoing bedding plant season. In this article, we hope to give you a basis for your bedding plant fertility program for use this spring.

Growers are responsible for providing 12 essential plant nutrients--six macronutrients (N, P, K, Ca, Mg, and S) and six micronutrients (Fe, Mn, Zn, Cu, B, and Mo). Fortunately, 10 of the nutrients can be added to the substrate prior to planting in quantities that will last for most bedding plant cropping periods. This makes a postplant liquid fertilization program easy to manage.

Incorporated fertilizers. A minimum base charge is placed in the mix (Table 1) and additional nutrition is applied as liquid feed. This gives the grower added flexibility in speeding up or holding back plants. Also, liquid feeding will provide a more uniform distribution of nutrients from cell to cell, tray to tray and even house to house than incorporation into the mix. Preplant nutrient additions fall into four categories: ❶ pH adjustment materials; ❷ phosphorus and sulfur sources; ❸ micronutrient sources; and ❹ a nitrogen and potassium starter charge.

The most commonly used pH adjustment material is dolomitic limestone. In addition to raising the pH to a desired level, dolomitic limestone also supplies *calcium* and *magnesium*. If a calcitic limestone and / or calcium hydroxide material is used instead of dolomite, growers should incorporate Epsom salts to supply ample Mg. An alternate source of calcium (for substrates not requiring a large lime charge such as coir-based substrates) is gypsum ($CaSO_4 \cdot 2H_2O$). Gypsum should be incorporated in the substrate if the pH adjustment material is not supplying sufficient calcium.

Table 1. Nutrient sources commonly added into greenhouse substrates during formulation.

Nutrient source	Rate per cubic yard: Soil-based substrates	Rate per cubic yard: Soilless substrates
For pH regulation and to provide calcium and magnesium		
Dolomitic limestone	0 to 10 lb	5 to 15 lb
To provide phosphorus		
Triple superphosphate	1.5 lb	2.25 lb (≤1 lb)*
To provide sulfur		
Gypsum (calcium sulfate)	1.5 lb	1.5 lb (1 lb)*
To provide micronutrients: iron, manganese, zinc, copper, boron, and molybdenum		
Esmigran®	5 lb	5 lb (2.5 lb)*
OR		
Micromax®	1 to 1.5 lb	1 to 1.5 lb (0.5 to 0.75 lb)*
To provide nitrogen and potassium (optional)		
Calcium nitrate	1 lb	1 lb (≤1 lb)*
Potassium nitrate	1 lb	1 lb (0 lb)*

*Plug substrate recommendations differ from other greenhouse substrates. Plug substrate recommendations (when different from the general rates) are given parenthetically. Soil-based substrates are not generally used or recommended for plugs.

Phosphorus additions are sometimes made during bedding plant substrate blending. Treble (triple) superphosphate (0-45-0) is used to supply phosphorus. Many growers used to use superphosphate (0-20-0), which also contained sulfur. Since triple superphosphate does not contain sulfur, growers should incorporate gypsum as a sulfur source (Table 1).

Some bedding plant growers will not incorporate phosphorus into the substrate, but will rely on the liquid fertilization program to supply P. If there is no P incorporated in your substrate, select a liquid fertilization program that does supply P. Even if phosphorus and sulfur are incorporated into the substrate, additional P and S may be required in the liquid fertilization program. Phosphorus and sulfur are both susceptible to leaching during production, and it is difficult to generalize on the rate of leaching for different growing systems. Monitor crops through substrate and tissue tests to determine if additional applications of P and S are needed in your liquid fertilization program.

Micronutrient programming for bedding plants is pH-dependent (see following section on substrate pH). An initial incorporation of micronutrients is recommended for all bedding plants; the need for subsequent applications in the liquid feed program should be determined by species requirements. For example, species requiring a low substrate pH generally require micronutrients in higher concentrations than species requiring a high substrate pH (see Table 2 for pH recommendations). If the pH is not kept in the recommended range, micronutrient additions should be adjusted accordingly: increase micronutrient additions to low-pH requiring species if the pH is too high; decrease or avoid micronutrient additions to high-pH requiring species if the pH is too low.

The addition of a *nitrogen* and *potassium* charge to the substrate at mixing is optional. If liquid feed can be started soon after planting then they are not necessary additions to the mix. The decision to incorporate N and K into the substrate is a matter of personal choice based on experience.

Substrate pH. The pH of the substrate, as estimated by measuring the pH of a substrate extract, is very important to plug and bedding plant nutrition. The pH directly affects the availability of many plant nutrients, especially micronutrients (Figure 1).

Too low of a pH can result in increased micronutrient availability that can lead to

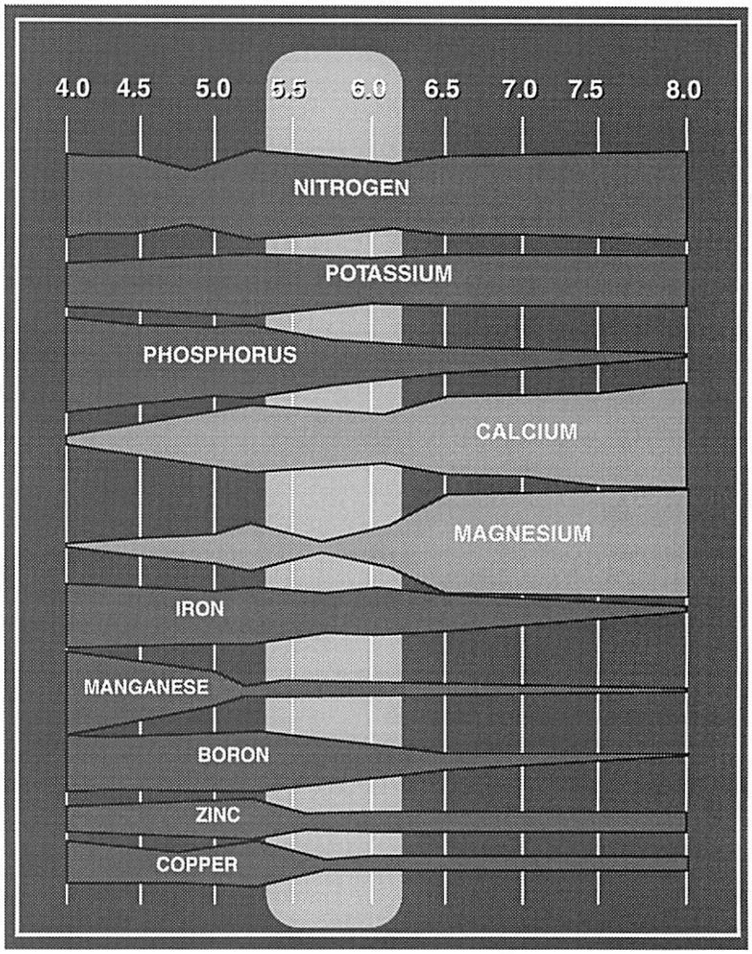

Figure 1. Influence of pH on the availability of essential nutrients in a soilless substrate containing sphagnum peat moss, composted pine bark, vermiculite, and sand. The pH range recommended for most greenhouse crops is indicated by the gold bar.

Table 2. Suggested substrate pH ranges for specific greenhouse crops grown in a soilless substrate. For crops not listed, the recommended pH range is 5.4 to 6.2.

Species	pH	Why?
Azalea	4.5 to 5.8	prevent Fe deficiency
Celosia	6.0 to 6.8	prevent Fe & Mn toxicity
Dianthus	6.0 to 6.8	prevent Fe & Mn toxicity
Easter lily	6.5 to 6.8	prevent F toxicity and Ca deficiency
Geranium	6.0 to 6.8	prevent Fe & Mn toxicity
Hydrangea (Blue)	5.2 to 5.6	prevent Fe deficiency and assist in blue coloration
Hydrangea (Pink)	5.8 to 6.2	prevent Fe deficiency and assist in pink coloration
Marigold (African)	6.0 to 6.8	prevent Fe & Mn toxicity
Pansy	5.4 to 5.8	prevent B & Fe deficiency; avoid *Thielaviopsis*
Petunia	5.4 to 5.8	prevent B & Fe deficiency
Petunia	5.4 to 5.8	prevent B & Fe deficiency
Salvia	5.4 to 5.8	prevent B & Fe deficiency
Snapdragon	5.4 to 5.8	prevent B & Fe deficiency
Vinca	5.4 to 5.8	prevent B & Fe deficiency; avoid *Thielaviopsis*

phytotoxic responses in some plant species. For example, a low pH in conjunction with excessive levels of iron and manganese can result in iron and / or manganese toxicity in celosia, geraniums and marigolds (Table 2). Calcium and magnesium deficiencies can develop when the pH is too low. There is a greater chance of ammonium toxicity problems in low pH conditions; and phosphorus leaching increases at a low pH.

At the other end of the spectrum, pH above 6.2 can lead to micronutrient deficiency problems such as iron deficiency chlorosis in petunias and pansies; and boron deficiency in salvia, petunias, and pansies (Table 2).

Most bedding plant crops (grown in a soilless substrate) can tolerate a pH of 5.4 to 6.8, but there are exceptions (Table 2). There are three categories of bedding plants with respect to substrate pH: ❶ species that require a low pH for best growth; ❷ species that require a high pH for best growth; and ❸ species that are relatively pH tolerant. Growers should target substrate pHs based on the species being produced and should treat species according to their requirements rather than using a blanket production system.

The ideal production situation is one where substrate pH is identical to the requirements of the particular species being produced; and no changes occur. Preventing pH changes will eliminate many of the nutrient problems encountered in bedding plant production. Unfortunately, there are many forces at work that affect substrate pH, and maintaining a constant pH is no easy task.

There are four major forces that affect the substrate solution pH during plant production: ❶ preplant materials such as dolomitic limestone put into the substrate and the substrate components themselves; ❷ the alkalinity of the irrigation water; ❸ the acidity / basicity of the fertilizers used during production; and ❹ the plant species being grown. With so many factors affecting pH, it's no wonder that pH stabilization is easier to write about than to implement!

Preplant materials. As previously mentioned, the starter lime charge should be adjusted based on the substrate components used in the mix and the desired starting pH. Although you know what starting substrate pH is best for the species you intend to grow, it may take from 24 hours to 7 days for the pH to adjust up to the desired level after the mix has been moistened. The length of this "equilibration period" will depend on the ratio of components, particle size and grade of lime used, the salts used to make the base charge, and the pH and alkalinity of your irrigation water.

Prior to using a mix, fill a few pots with it, water them in with distilled water, and set them in the greenhouse for a few days, keeping them moist. After this equilibration period, measure the pH of the substrate; it should be within the range targeted for the species being grown. If it is far off target, you may need to adjust your pH control strategy.

Water alkalinity. The alkalinity of your irrigation water is a key player in the substrate solution pH. The greater the alkalinity, the greater the tendency for substrate pH to rise over time. Research at NCSU that varied the initial lime charge in plug trays and varied the alkalinity of irrigation water used in plug production shows that over time, the effect of the alkalinity in the irrigation water far exceeds that of the initial lime charge. Acidification of high alkalinity water may be required to prevent an undesirable rise in substrate pH.

Cooperative research between Allen Hammer and Brian Whipker at Purdue University and the authors of this article led to the development of an Excel® spreadsheet that allows users to input their water pH and alkalinity then select sulfuric, phosphoric, or nitric acid to use as an acidifying agent to reach a target pH or alkalinity. The spreadsheet modules calculate the nutrient additions from the acid injection and will report your acidification costs, if you input the price per gallon for the acid you wish to use. You can acquire a copy of this spreadsheet to aid in your water acidification needs via the world wide web (http://www2.ncsu.edu/ncsu/cals/hort_sci/floriculture/) or by contacting the authors.

Fertilizer Acidity / Basicity. Most of the fertilizer salts we use have some effect on the substrate pH (Table 3). Some such as 21-7-7 are very acid (high acidity) while others such as 15-0-15 are fairly basic (high basicity). Fertilizer acidity / basicity relates to how the pH of the substrate solution changes after the fertilizer is applied and plants absorb nutrients from the substrate. The ratings given in Table 3 are used by fertilizer manufacturers, but are based on the fate of fertilizer salts in a mineral based soil out in the field as measured by researchers in the 1930s! Further research is

Table 3. Potential acidity or basicity, percent of total nitrogen in the ammonium plus urea form, and Ca, Mg, and S components (when these are ≥ 0.2%) for several commercial fertilizers.

Fertilizer*	Potential acidity or basicity**	NH_4 (%)***	Ca (%)	Mg (%)	S (%)
21-7-7	1,700 A	90	—	—	10.0
21-7-7	1,560 A	100			
20-2-20	800 A	69			
20-18-18	710 A	73	—	—	1.4
24-7-15	612 A	58	—	1.0	1.3
20-18-20	610 A	69	—	—	1.0
20-20-20	583 A	69			
20-9-20	510 A	42	—	—	1.4
20-20-20	474 A	69			
16-17-17	440 A	44	—	0.9	1.3
20-10-20	422 A	40			
21-5-20	418 A	40			
20-10-20	393 A	38			
21-7-7	369 A	100			
15-15-15	261 A	52			
17-17-17	218 A	51			
15-16-17	215 A	47			
15-16-17	165 A	30			
20-5-30	153 A	56			
17-5-24	125 A	31	—	2.0	2.6
20-5-30	118 A	54	—	0.5	—
20-5-30	100 A	54			
15-11-29	91 A	43			
15-5-25	76 A	28	—	1.3	—
15-10-30	76 A	39			
20-0-20	40 A	25	5.0	—	—
21-0-20	15 A	48	6.0	—	—
20-0-20	0	69	6.7	0.2	—
16-4-12	73 B	38			
17-0-17	75 B	20	4.0	2.0	—
15-5-15	135 B	28			
13-2-13	200 B	11	6.0	3.0	—
14-0-14	220 B	8	6.0	3.0	—
15-0-15	319 B	13	10.5	0.3	—
15.5-0-0	400 B	6	22.0	—	—
15-0-15	420 B	13	11.0	—	—
13-0-44	460 B	0			

*Notice that identical analyses can have different acidities, basicities, and percent NH_4, depending on the manufacturer.

**A = pounds of calcium carbonate limestone required to neutralize the acidity caused by using one ton of the specified fertilizer. B = equivalent pounds of calcium carbonate limestone added by using one ton of the fertilizer.

***Refers to the percentage of total nitrogen that is in the ammonium plus urea forms; the remaining nitrogen is nitrate-N.

needed to better define acidity and basicity of common fertilizers in greenhouse substrates.

We can lower, raise, or hold constant the pH of plugs and bedding plants by fertilizer selection. Unfortunately, most acidic fertilizers also have a correspondingly high proportion of ammoniacal nitrogen and cannot be relied on as the only means of reducing the substrate pH. For example, if too much ammoniacal nitrogen is applied in plug production, the plants will stretch excessively and will develop undesirably succulent growth. We will discuss the effects of ammoniacal and nitrate nitrogen in more depth when we address post-planting fertilization.

Species effect on substrate pH. Research at NCSU has shown that bedding plants will modify the substrate pH during germination and seedling growth (Figure 2). However, many species change the pH to a level that is not best for their growth! For example, celosia and dianthus (both grow best at a higher pH) tend to lower the substrate pH. Vinca raised the substrate pH, though vinca grows best at a lower pH. Growers must be aware of species effects on substrate pH, especially when monitoring the pH of a plug crop during production. Imagine the nightmare of a plug producer basing their entire pH control program on samples of a single species; or on a combined sample of different species. Do you monitor the substrate pH of your species *separately* and adjust pH according to sample results? Our research results indicate you should.

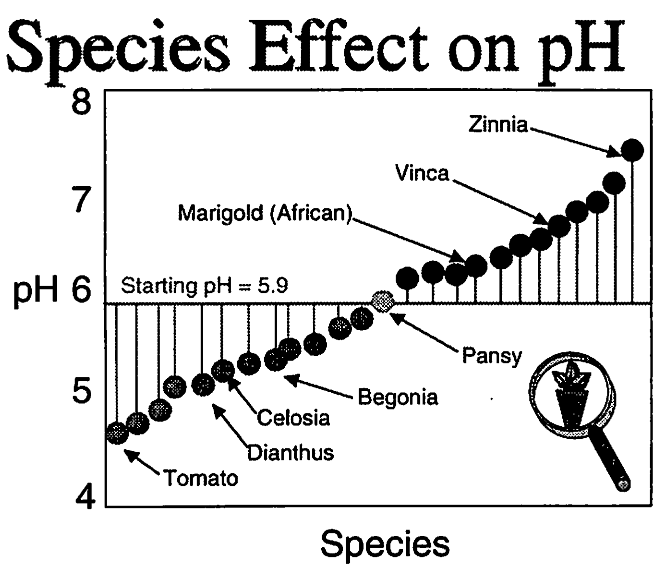

Figure 2. Effects of 25 bedding plant species on substrate pH.

Strategies to control pH. We need to establish pH base lines for all major bedding plant species, similar to those suggested in Table 2. Next, upper and lower "decision points" must be determined for each species. Decision points are limits that determine when action must be taken to correct or prevent an out-of-range pH. We have already described the tools available to us in regulating pH for a given species -- preplant materials, regulation of water alkalinity, and fertilizer selection tailored for each species. The final stage of a pH stabilization strategy is to decide how to control pH in your particular production system, then to monitor frequently to assure that you are within the acceptable pH range for each of your crops.

The example pH plot in Figure 3 is assuming a pH base line of 5.8; an upper decision limit of 6.2; and a lower decision limit of 5.4. For this hypothetical species, a grower would target pH 5.8 when adding the liming components into the substrate prior to seeding. They would want to take corrective measures to lower pH if sampling showed a substrate pH of 6.2 or above. Corrective measures to lower pH include: ❶ acidifying your water down to pH 5.8 (neutralizing ~80% of the alkalinity in your irrigation water); ❷ discontinuing the use of basic residue fertilizers, such as calcium nitrate and using acid-residue fertilizers to lower the pH, if plants are capable of tolerating the ammoniacal nitrogen; and ❸ in severe cases, drenching with aluminum sulfate or iron sulfate to rapidly lower pH. The substrate pH would need to be raised if it fell below 5.4. Corrective measures to raise pH include: ❶ discontinuing irrigation water acidification, if any is employed; ❷ using basic-residue fertilizers to raise the substrate pH; and ❸ in severe cases, injecting potassium bicarbonate to increase the alkalinity of your irrigation water to increase the substrate solution pH.

Substrate pH Regulation

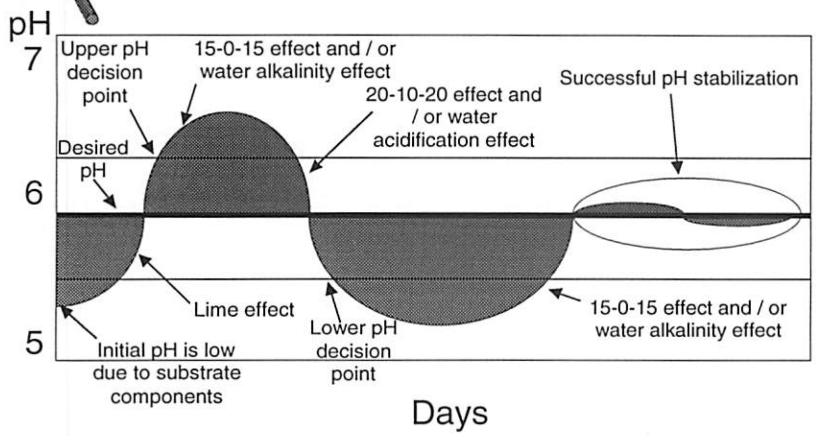

Figure 3. An example pH regulation strategy based on a desired pH of 5.9.

There is still much to learn about pH regulation and how to incorporate it into a nutrition program. We have only begun to outline standards, but we hope to eventually create control graphs similar to Figure 3 for most bedding plant species produced. Through careful monitoring and precise production management, pH-related nutrition problems can be avoided.

Postplant fertilization. There are three aspects of postplant fertilization to be covered in this article: ❶ rate and frequency of fertilization; ❷ pH effects of fertilizers; and ❸ ammonium versus nitrate nitrogen in a fertilization program.

The exact *fertilizer concentration* to use depends on stage of growth, plant species, desired rate of growth, leaching percentage during irrigation, and *fertilizer application frequency*. As frequency of fertilization increases, fertilizer concentration should be decreased. For bedding plant flat systems, common choices are fertilization at each watering, each week, or every two weeks (Table 4); while for plugs, choices are fertilization at each irrigation, every other irrigation, or every 3rd irrigation (Figure 4).

Young seedlings and plugs are sensitive to fertilizer salts and have a very low fertilizer requirement, thus the lower rates. Recommendations more specific to plug production are given in Figure 4.

Growers must vary the fertilizer concentration or the application frequency for bedding plant species because species have very different nutrient requirements. Crops with light needs include broccoli, cabbage, cauliflower, impatiens, and pansy. They should be fertilized at or below the lowest concentrations listed in Table 4 and Figure 4. Bedding plants requiring heavy fertilization include begonia, dusty miller, portulaca, verbena, and vinca. These should be fertilized at the high end of the ranges given. Other species not listed should be fertilized using mid-range values.

Required rate of growth is difficult to predict for bedding plants. During a dark, rainy period, fertilization should be reduced to prevent excessive plant stretch. When the market does not open up as rapidly as anticipated, growers

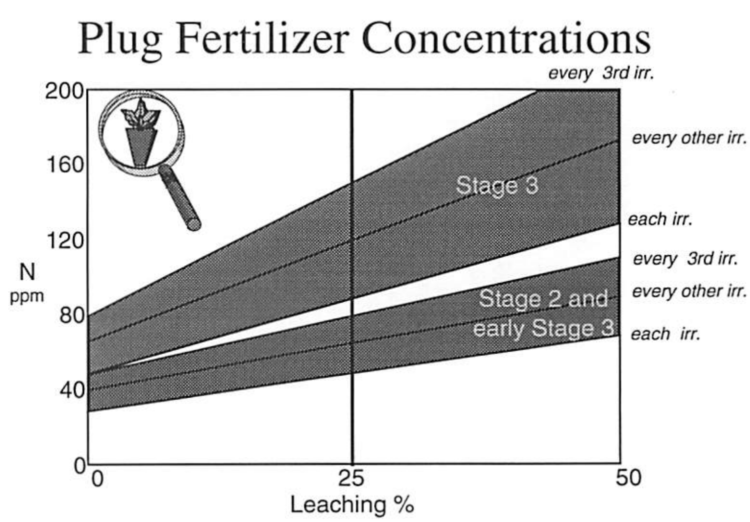

Figure 4. Recommended nitrogen (N) fertilization rates based on plug stage of development, frequency of fertilizer application, and degree of leaching during irrigation.

Table 4. Postplant fertilizer rate and frequency.[Z]

N conc. (ppm)[Y]	Frequency	Production stage
50 to 75	as needed	plug—late Stage 2 through mid-Stage 3
100 to 150	as needed	plug—remainder of Stage 3
100 to 200[X]	each watering	finish flats or pots
200 to 300[X]	weekly	finish flats or pots
450 to 500[X]	every 2 weeks	finish flats or pots

[Z]Fertilizer concentrations to use for various bedding plant production stages. Concentrations given are for nitrogen. The phosphorus and potassium concentrations depend on the selected fertilizer's ratio.

[Y]Exact fertilizer application concentration and frequency depends on the plant species, the desired growth rate, and the leaching percentage.

[X]These are three alternative fertilization programs. Use only one.

may need to hold back bedding plants, and again fertilization should be reduced. There will also be cases where the market may open earlier than anticipated and crops will need to be "pushed" (increase fertilization).

Leaching percentage during irrigation (the percentage of irrigation solution that drains out of the container after irrigation) is a large factor in fertilization requirements of plants. The greater the percent of leachate, the greater chance for loss of fertilizer salts. In general, a greater percent of leaching requires a greater fertilization rate.

The importance of *substrate pH control* was outlined previously. Fertilizers applied to bedding plants may either raise or lower the pH. Postplant pH can be controlled to a certain degree through fertilizer selection (Table 3). Fertilizers with potential acidity will lower substrate pH while fertilizers with potential basicity will raise the substrate pH. One factor in selecting a fertilizer should be pH regulation.

Another factor in selecting a fertilizer is the *ammonium and nitrate content and ratio.* Ammoniacal nitrogen stimulates greater leaf expansion and more internode elongation than nitrate nitrogen. However, too high a percentage of ammoniacal nitrogen (greater than 40%) can lead to ammonium toxicity problems and should be avoided.

Use fertilizers that contain 15 to 40% of the nitrogen in the ammoniacal or urea form (Table 3) to stimulate rapid growth and more lush growth. Use fertilizers containing less than 15% ammoniacal or urea nitrogen (Table 3) to help keep plants compact and keep growth "hard".

Acid fertilizers tend to contain higher amounts of ammoniacal nitrogen while alkaline fertilizers contain a high proportion of nitrate nitrogen (Table 3). This means that if you wish to use a high nitrate fertilizer for compact growth, the substrate pH may rise over time; and if you use a high proportion

Table 5. Quantities (ounces) of fertilizer or fertilizer salts to dissolve in 100 gallons of water to make solutions containing 50 to 250 ppm each of nitrogen (N) and potassium (K_2O).

	Concentration of N and K_2O (ppm)			
Fertilizer or salts	50	75	100	250
Acid-residue sources	oz/100 gallons			
20-10-20*	3.34	5.0	6.7	16.7
20-9-20*	3.34	5.0	6.7	16.7
ammonium nitrate +	1.23	1.85	2.5	6.15
potassium nitrate +	1.50	2.25	3.0	7.5
monoammonium phosphate (20-10-20)*	0.54	0.81	1.1	2.7
Basic-residue sources	oz/100 gallons			
13-2-13 (-6Ca-3Mg)*	5.13	7.7	10.3	25.65
14-0-14 (-6Ca-3Mg)	4.76	7.14	9.5	23.8
15-0-15 (-9.5Ca-1Mg)	4.45	6.68	8.9	22.25
15-5-15 (-5Ca-2Mg)*	4.45	6.68	8.9	22.25
17-0-17 (-4Ca-2Mg)	3.92	5.88	7.83	19.6
potassium nitrate	1.51	2.28	3.03	7.58
+ calcium nitrate	1.76	2.64	3.52	8.8
+ magnesium nitrate (13-0-13-6.6Ca-3.3Mg)	1.8	2.7	3.6	9.0

*These formulations also contain phosphorus (P_2O_5).

ammoniacal nitrogen fertilizer, the substrate pH will drop. Close monitoring of substrate pH is important to prevent undesirable fluctuations due to fertilization programs.

Fertilizer formulations. As mentioned above, fertilizer selection for postplant fertilization should be based on desired pH, desired growth habit (rapid versus compact), species being grown, calcium and magnesium supplied via irrigation water source, and preplant incorporation programs (how much phosphorus is needed). Table 5 lists some common fertilizers and amounts to add to make various ppm solutions. It has the sources categorized by pH effect--acid-residue and basic-residue.

In the next issue of the Bulletin, we will present information on nutritional testing for substrates, plant tissue, and irrigation water.