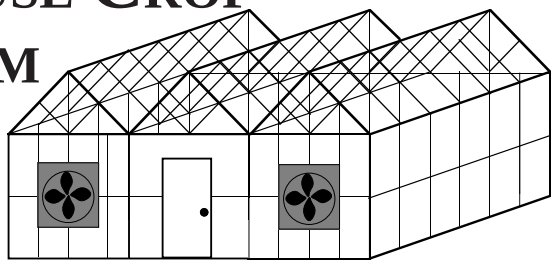
DESIGNING A GREENHOUSE CROP FERTILIZATION PROGRAM



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INTRODUCTION

Correct crop nutrition is essential for successful plant production. With so many factors affecting plant nutrition and an ever increasing number of fertilizers and fertilizer systems to choose from, growers need hands-on advice on how to put it all together. The following handout has been prepared to serve as a reference for your floriculture crop nutrition questions. The sections are divided into preplant fertilization, post-planting fertilization programming, corrective procedures for nutrient deficiencies, and fertilizer formulating. This handout is designed to give you the nuts and bolts of crop nutrition and will offer you the tools to set up a successful crop nutrition program, regardless of which floriculture crops you grow.

PREPLANT FERTILIZATION

There are four categories of preplant fertilization: ❶ dolomitic limestone incorporation (supplying calcium and magnesium); ❷ incorporation of superphosphate to supply phosphorus and sulfur; ❸ addition of micronutrients; and ❹ adding a "starter charge" of nitrogen and potassium. For many floricultural crops, a preplant incorporation program can supply sufficient levels of the macronutrients phosphorus, calcium, magnesium, sulfur; and the micronutrients iron, manganese, zinc, copper, boron, and molybdenum to last the entire cropping period.

Limestone Incorporation

Since most greenhouse substrate components are acidic, agricultural limestone is added to raise the pH level (Table 1). Dolomitic limestone is usually used, since it supplies both calcium and magnesium. However, many commercial substrates also contain hydrated lime (quick lime) as a pH regulator. In general, soil-based substrates can require from 0 to 10 lbs of dolomitic limestone per cubic yard, while soilless substrates typically require approximately 10 lbs per cubic yard. This amount should supply sufficient calcium and magnesium for most floricultural crops, provided the pH is maintained within the recommended range.

If the substrate does not require liming to raise the pH level, then gypsum (calcium sulfate) should be incorporated at 5 lbs/yd^3 to supply sufficient calcium. When growing in unlimed substrate, magnesium levels in the crop should be monitored to determine when an occasional application of this nutrient is required.

Superphosphate Incorporation

Treble superphosphate (0-44-0) is the main source of phosphorus available for substrate incorporation. Mix equal weights of 0-44-0 with gypsum and incorporate this mixture at the rates given in Table 1. Soilless substrates require higher amounts of super phosphate because phosphorus is more easily leached from a soilless substrate than from one containing soil. However, excess phosphates in irrigation runoff is possible and should be prevented.

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

Nutrient source	Rate per cubic yard	
	Soil-based substrates	Soilless substrates
To provide calcium and magnesium		
Dolomitic limestone	0 to 10 lb	10 to 15 lb
To provide phosphorus and sulfur		
Treble superphosphate (0-44-0)	1.5 lb	2.25 lb
+ gypsum (calcium sulfate)	1.5 lb	2.25 lb
To provide micronutrients: iron, manganese, zinc, copper, boron, and molybdenum		
Esmigram®	5 lb	5 lb
OR		
Micromax®	1 to 1.5 lb	1 to 1.5 lb
To provide nitrogen and potassium (optional)		
Calcium nitrate	1 lb	1 lb
Potassium nitrate	1 lb	1 lb

Addition of Micronutrients

There are several commercial preplant micronutrient mixtures available for greenhouse use (Table 1). Some are composed of micronutrient salts; these offer the shortest supply period. Others, such as Esmigran®, are mixtures of salts impregnated into clay granules, which allow slower release of salts with time and also offer larger particle size and total volume for easier blending during substrate formulation than simple powdered salts.

An alternative method of supplying micronutrients is liquid application (as a substrate drench) soon after planting. Products that are appropriate to apply in this manner, such as STEM® (8 oz/100 gallons; apply at a normal watering volume), Sol-Trace® (8 oz/100 gallons), or Chemec® (2.5 lb/ 100 gallons), provide micronutrients for about 3 to 4 months. Many commercial soluble fertilizers also contain micronutrients; some sold specifically for use on soilless substrates contain elevated levels of micronutrients. If these products are used, care must be taken to avoid over application of micronutrients that could lead to micronutrient imbalances in the crop.

Nitrogen and Potassium

The addition of nitrogen and potassium in the substrate during blending is optional (Table 1). Some production systems can benefit from a preplant incorporation of nitrogen and potassium. An example would be seedling germination under mist, where overhead application of N and K may not be feasible. A 2 to 3 week supply of N and K can be provided by incorporating one pound each of calcium nitrate and potassium nitrate per cubic yard of substrate.

Slow-Release Fertilizers

Many growers utilize slow-release fertilizers in their fertilization program. These products can be incorporated into the substrate during mixing or added later to pots as a top dressing. If slow-release products are used in a production system, adjustments in the nutrients supplied should be made for both preplant incorporation and post-planting feeding strategies.

POST-PLANTING PROGRAMMING

Frequency of Application

The preplant nutrient additions should take care of the crop needs for calcium and magnesium as long as the pH level remains in the desired range. The superphosphate and possibly gypsum addition will meet the phosphorus and sulfur needs. Finally, the six micronutrients are provided for the crop by the single micronutrient mix product which was incorporated into the substrate. Now a continuous liquid fertilization program is needed for nitrogen and potassium. In a soilless substrate where phosphorus leaches out easily, this nutrient is often added along with nitrogen and potassium.

The first question to answer when developing a continuous fertilization program is how frequently should fertilizer be applied. There are two answers; approximately once per week and with every watering. Both programs work equally well. Labor inputs determine which to use. In a greenhouse where a grower must bring a fertilizer proportioner to the end of each bench, connects it, and waits for application to be made before moving to the next bench, it is best to apply only once per week. In a larger firm where fertilizer is injected into the main water lines, it is easiest to apply fertilizer with every watering. To do otherwise, growers would constantly have to turn the proportioner on and off and flush water lines.

Rate of Nitrogen

Once the frequency of fertilization has been decided the next decision is the rate of nitrogen to use. This is not as difficult a decision as it might appear to be. Aside from plug seedlings, the concentration of nitrogen ranges from 240 to 720 ppm (1 to 3 lbs of 20% nitrogen fertilizer per 100 gallons) when applied weekly and 90 to 255 ppm when applied with every watering. Once a crop is categorized into a very light, light, moderate, heavy, or very heavy fertilization category it is easy to assign a rate to it. Table 2 lists concentrations of a 20% nitrogen fertilizer to be used for weekly fertilization and for fertigation (with every watering) for various crops.

It is not necessary to use a fertilizer containing 20% nitrogen. Fertilizer ratios of 1-0-1 and 1-1-1 are available in grades such as 15-0-15, 15-15-15, and 25-0-25. If the fertilizer contains 15 percent nitrogen, one-third more is used than for a material containing 20 percent nitrogen; if it contains 25 percent nitrogen, one-fifth less is used in each 100 gallons of water than would be used if it contained 20 percent nitrogen.

Ratio of Potassium to Nitrogen

Most crops develop best on a fertilizer equally balanced in nitrogen (N) and potassium (K_2O). There are a few exceptions. The Elatior begonia grows faster and develops more side shoots when it is fertilized with a ratio of 2 parts nitrogen to 1 part potassium (Table 3). The azalea requirement is similar in that a 3:1 ratio is best. The carnation requirement is quite different since a ratio of 2 parts nitrogen to 3 parts potassium is favored.

Ratio of Phosphorus to Nitrogen.

It is possible to add sufficient phosphorus to substrate to last for the duration of a three to four month crop. Then, phosphorus is not needed in the continuous fertilizer program. But we do not always know how much phosphorus is in the commercial substrate. Or, phosphorus may leach faster than anticipated because the substrate pH level is allowed to fall adversely low. Or, we are growing a long term crop such as cyclamen or azalea during which phosphorus runs out. In these latter three cases it is necessary to add phosphorus into the continuous fertilization program.

Traditionally, too much phosphorus has been used in greenhouse programs. Ultimately the excess ends up in ground water. How much is enough? The exact answer is not known. However, applying phosphorus at a concentration equal to half of the concentration of nitrogen will be more than adequate for the above situations and for the situation where no phosphorus has

Table 2. Standard concentration requirements of fertilizers containing 20 percent nitrogen for several greenhouse crops.

Crop	Concentration category	Concentration* Weekly oz/100 gallons	Weekly g/l	Constant oz/100 gallons	Constant g/l
Daffodil	None	—	—	—	—
Iris	None	—	—	—	—
Hyacinth	None	—	—	—	—
Tulip**	Very light	—	—	—	—
Snapdragon	Very light	16	1.2	6	0.5
Bedding plants	Very light	16	1.2	6	0.5
Elatior begonias	Very light	17	1.3	8.5	0.6
Azalea	Light	20	1.5	—	—
Gloxinia	Light	20	1.8	10	0.8
Rose	Moderate	32	2.4	10	0.8
Carnation	Moderate	32	2.4	13.5	1.0
Geranium	Moderate	32	2.4	13.5	1.0
Easter lily	Moderate	32	2.4	13.5	1.0
Chrysanthemum	Heavy	40	3.0	15	1.1
Poinsettia	Very heavy	48	3.6	17	1.3

*13.5 oz of 20 percent nitrogen fertilizer/100 gallons = 200 ppm nitrogen.

**As an insurance against nitrogen and calcium deficiencies, calcium nitrate should be applied at the rate of 32 oz/100 gal lon (2.4 grams/liter) at the start and at the midpoint of the growth-room stages and at the start of greenhouse forcing.

been added to the substrate during its formulation. Summarizing, the best fertilizer formulation for general crops is: 2 nitrogen (N) : 1 phosphorus (P_2O_5) : 2 potassium (K_2O). A fertilizer which fits this ratio is 20-10-20. This fertilizer has, in fact, become a standard of the industry.

Ammonium Versus Nitrate Nitrogen

There is one final decision to be made in the process of formulating a fertilization program. That concerns the choice of a nitrogen form. Three forms of nitrogen are generally used for fertilization: nitrate (NO_3^-), ammonium (or ammoniacal) (NH_4^+), and urea. Plants vary in response to these forms. The response to ammonium and urea is generally identical in plants since urea must be converted to ammoniacal nitrogen to be assimilated in plants. Plants, such

Table 3. Nitrogen (N) : potassium (K_2O) ratios for various crops.

Crop	N : K_2O
General	1 : 1
Azalea	3 : 1
Begonia	2 : 1
Carnation	2 : 3

as azalea and rhododendron, that grow well in highly acid root media develop best on a high proportion of ammonium nitrogen. Other crops, however, may be injured when more than 50 percent of the total nitrogen is provided as ammonium plus urea. Best growth is obtained when a mixture of nitrate plus ammonium and/or urea is supplied. If fertilizers are selected having 40% or less of the total nitrogen in the ammonium plus urea form, no ammonium toxicity should be encountered with any crops in any season.

Since ammonium toxicity is a threat, growers may be tempted to drop ammonium out of the fertilizer altogether. This would be a mistake. Plants tend to be "hard" when grown on all nitrate nitrogen. That is, leaves stems and overall plant size is smaller. For plants in general, it is best to use a mixture of nitrate and ammonium which includes between 15 and 40% (50% maximum) of the nitrogen in the ammonium form. There are situations such as in plug seedling production when it is desirable to force the plants into a compact growth form. A 100% nitrate nitrogen fertilizer is used in these situations.

The standard greenhouse fertilizer used until this past decade was 20-20-20. This fertilizer contains approximately 70 percent of its nitrogen in the ammonium plus urea forms. Ammonium toxicity was not attributed to 20-20-20 fertilizer until soilless substrates became popular. Soilless substrates tend to be lower in pH level than soil-based substrates. The optimum pH for bacteria that convert ammonium-nitrogen to nitrate-nitrogen in the soil is slightly above 7.0. In the pH range of 6.0 to 7.0 used for soil-based substrates, adequate populations of bacteria develop to reduce the high level of ammonium plus urea supplied by 20-20-20 fertilizer. This is not true for soilless substrates, where pH values below 6.0 are established, and ammonium toxicity is a greater concern in soilless substrates.

Ammonium toxicity is a greater problem in the winter than in the summer. Substrate temperatures are cooler in the winter. As a consequence, the nitrifying bacteria responsible for conversion of ammonium to nitrate are less active. Years ago, switching from a 20-20-20 to a 15-15-15 formulation in the winter was known to give better results. It is now known that the drop in ammonium plus nitrate nitrogen from 70 percent in 20-20-20 to about 50 percent in 15-15-15 was probably the reason.

CORRECTIVE PROCEDURES

A three part strategy has been used in this presentation to develop a fertilization program. Part I involved preplant additions of nutrients to the substrate during its formulation. These additions were designed to meet the total crop needs of as many nutrients as possible. Part II covered the continuous liquid fertilizer program throughout the crop time. In that section nutrients were confined to nitrogen, potassium, and possibly phosphorus. We now cover Part III, corrective procedures for nutrient deficiency situations.

Even the best planned program will go astray in time. Plant demand for nutrients changes with weather conditions. Substrate pH level slips out of range allowing nutrients to leach or be tied up. The amount of leaching during watering and fertilization may vary from the level we intend. These and many other factors bring about decreases or increases in the availability of individual nutrients. When this happens onetime adjustments are required. After the adjustment, the prior fertilization program can be reestablished. Table 4 offers corrective procedures to use when any one of 10 nutrient deficiencies occurs.

FORMULATING FERTILIZERS

Complete fertilizers (those containing nitrogen, phosphorus, and potassium) are commercially available in a number of grades. Many growers formulate their own fertilizers, thus saving a significant part of their fertilizer bill and making possible an even wider range of

grades. Most fertilizers are formulated from combinations of two or more of nine fertilizer carriers. For example, 1 pound of potassium nitrate added to 1 pound of ammonium nitrate yields 2 pounds of 23-0-22-grade fertilizer.

Several formulations that a grower can easily make are presented in Table 5. The first nine fertilizer entries are the fertilizer carriers from which all of the subsequent fertilizer formulas are derived. For example, an 18-0-22 formula fertilizer can be formulated by blending 1 pound of ammonium nitrate plus 2 pounds of potassium nitrate plus 1 pound of ammonium sulfate together. This formulation was determined by locating the 18-0-22 formula in the "Analysis" column. Then, the three numbers 1, 2, and 1 were located in the row after this formula. Each of these three numbers was traced to the "X" above it and then to the fertilizer carrier to the left of the "X."

Additional formulations can be found in Table 6. Three common complete fertilizers are listed first followed by four "make-your-own" formulations. The percentage of total nitrogen in ammonium plus urea form (NH_4^+) in each is given. Quantities to dissolve in 100 gallons of water to yield concentrations of 50 to 600 ppm each of nitrogen and potassium are also given.

While the make-your-own fertilizers do not contain micronutrients or dye, commercial preparations are available. They include Compound 111®, which is added at the rate of 1 pound per 40 pounds of macronutrient formulation, and Mitrel M®, which is added at the rate of 8 ounces per 100 pounds of macronutrient formulation and will provide a dye and micronutrients in chelated form. The complete set of micronutrients without dye may be added as STEM® at the rate of 8 ounces per 100 pounds of fertilizer formulation; as Masterblend4 Formula 222 Micronutrient Additive® at 1.25 pounds per 100 pounds of fertilizer; as Sol-Trace® at 8 ounces per 100 pounds of fertilizer; as Olympic Minor Element Soluble® at 8 ounces per 100 pounds of fertilizer; or as CHL-MIN® at 1 pound per 50 pounds of fertilizer.

Table 4. Fertilizer sources and rates for correction of various nutrient deficiencies.

Deficient nutrient	Fertilizer source	Rate of application* oz/100 gal	Rate of application* g/l
P	Switch to a complete fertilizer containing N-P-K for the continual program		
	OR one application of diammonium phosphate or monopotassium phosphate	32	2.4
Ca	Switch part or all of the N source to calcium nitrate for a few weeks		
Mg	Magnesium sulfate (Epsom salts; 10% Mg)	32	2.4
S	Magnesium sulfate (13% S)	32	2.4
	OR switch N or K source to ammonium sulfate (24% S) or potassium sulfate (18% S) for a few weeks		
Fe	Iron chelate (Sequestrene® 330; 10% Fe) or ferrous sulfate (20% Fe)	4	0.300
	OR foliar spray ferrous sulfate or Sequestrene® 330 iron chelate	4	0.300
Mn	Manganese sulfate (28% Mn)	0.5	0.038
	OR foliar spray manganese sulfate	2	0.150
Zn	Zinc sulfate (36% Zn)	0.5	0.038
	OR switch to the fungicide Zineb and spray at the recommended rate monthly		
Cu	Copper sulfate (25% Cu)	0.5	0.038
	OR foliar spray tri-base copper sulfate (53% Cu)	4	0.300
B	Borax (11% B)	0.5	0.038
	OR Solubor (20% B)	0.25	0.019
Mo	For soil-based substrates, drench once with sodium molybdate (38% Mo) or ammonium molybdate (54% Mo)	0.027**	0.002
	For soilless substrates, drench once with sodium or ammonium molybdate	2.67	0.200
	OR foliar spray sodium or ammonium molybdate with a spreader-sticker	2	0.150

*These corrective procedures are to be applied once. Subsequent applications should be made only after soil and foliar analysis test indicate the need. All fertilizers are to be applied as a substrate drench unless foliar spray is specified.

**Dissolve 1 ounce sodium or ammonium molybdate in 40 fl.oz. of water. Use 1 fl.oz. of this stock solution in each 100 gallons of final-strength fertilizer solution.

Table 5. Amounts of fertilizer carrier sources to combine in making various fertilizer formulas.

Fertilizer		Nutrient sources*											
Name	Analysis	33-0-0	13-0-44	15.5-0-0	16-0-0	21-0-0	45-0-0	0-0-60	12-62-0	21-53-0	% of N as NO_3^-	Cost (¢/lb)****	Reaction in substrate*****
Ammonium nitrate	33-0-0	x									50	12	A
Potassium nitrate	13-0-44		x								100	26	N
Calcium nitrate	15.5-0-0			x							94	10	B
Sodium nitrate	16-0-0				x						100	10	B
Ammonium sulfate	21-0-0					x					0	5	A
Urea	45-0-0						x				0	14	SA
Potassium chloride**	0-0-60							x			—	8	N
Monoammonium phosphate	12-62-0								x		0	34	A
Diammonium phosphate***	21-53-0									x	0	16	SA
Chrysanthemum green	18-0-22	1	2			1					53	17	A
General summer	20-10-24	1					1	2		1	17	12	A
General low phosphate	21-4-20	7						4		1	45	12	A
General summer	21-17-20	1					2	3		3	10	12	A
General	17-6-27	4						4		1	43	11	A
UConn Mix	19-5-24		6	2			2		1		51	22	N
Editor's favorite	20-5-30		13				4			2	43	22	SA
20-20-20 substitute	20-20-22		4				1			3	33	21	SA
Starter and pink hydrangea	12-41-15		1						2		35	31	SA
Starter and pink hydrangea	17-35-16						1	4		10	0	14	SA
N-K only	16-0-24	2			1			2			60	10	SA
N-K only	20-0-30	1	2								72	21	SA
Blue hydrangea	13-0-22					2		1			0	6	VA
Blue hydrangea	15-0-15					3		1			0	6	VA
Acid	21-9-9	3	1			7		1		2	21	10	VA
Spring carnation	11-0-17				5			2			100	10	B
Winter nitrate	15-0-15		1	2							96	15	B
Winter potash	15-0-22		1	1							97	18	B
Lily substitute	16-4-12	1	4	6						1	78	16	N
High K	15-10-30		7	1						2	72	22	N

*For names of fertilizer carrier sources, see the first nine entries in the fertilizer "Name" column.

**Use crystalline potassium chloride if possible.

***Diammonium phosphate may be pelletized and coated. To dissolve, use very hot water and stir vigorously. Do not worry about sediment.

****Based on lowest available prices published by greenhouse supply firms. Does not include labor costs.

*****B = basic, N = neutral, SA = slightly acid, A = acid, VA = very acid.

Table 6. Quantities of fertilizers or fertilizer carriers to dissolve in 100 gallons of water to make solutions containing concentrations of 50 to 600 ppm each of nitrogen (N) and potassium (K_2O).

Fertilizer	% NH_4^+ + urea	Concentration of N and K_2O (ppm)						
		50	100	200	300	400	500	600
		oz/100 gal						
20-20-20*	70	3.3	6.7	13.3	20.0	26.7	33.4	40.0
15-15-15*	52	4.5	8.9	17.8	26.7	35.6	44.5	53.4
20-10-20	40	3.3	6.7	13.3	20.0	26.7	33.4	40.0
Ammonium nitrate	36	1.4	2.9	5.7	8.6	11.4	14.3	17.1
+ potassium nitrate (23-0-23)		1.5	3.0	6.1	9.1	12.1	15.2	18.2
Calcium nitrate	4.5	3.0	6.0	12.0	18.0	24.0	30.0	36.0
+ potassium nitrate (15-0-15)		1.5	3.0	6.0	9.0	12.0	15.0	18.0
Ammonium nitrate	40	1.2	2.5	4.9	7.4	9.9	12.3	14.8
+ potassium nitrate		1.5	3.0	6.0	9.0	12.0	15.0	18.0
+ monoammonium phosphate (20-10-20)*		0.5	1.1	2.2	3.2	4.3	5.4	6.5
Calcium nitrate	2.6	1.8	3.5	7.0	10.5	14.1	17.6	21.1
+ magnesium nitrate		1.8	3.6	7.2	10.8	14.4	18.0	21.6
+ potassium nitrate (13-0-13-6.6 Ca-3.3 Mg)		1.5	3.0	6.1	9.1	12.1	15.2	18.2

*These formulations also contain phosphorus (P_2O_5) at equal or half the concentration of nitrogen.