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FORMULATING GREENHOUSE FERTILIZERS

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The seemingly formidable task of designing the liquid fertilizer programs for the many crops grown in the greenhouse is not so difficult if a few rules are followed during their design. These rules will be discussed first, then a number of fertilizer formulations will be presented.

Rate and Timing of Nitrogen

Our first consideration should be nitrogen because it is generally applied in the largest quantity and because it leaches from root media faster than other nutrients. The rate of nitrogen needed will depend upon the frequency of application. Equally satisfactory results can be obtained from either of the common frequencies of liquid fertilizer application. These are: weekly and application with each watering (known as constant injection or fertigation). Presented in Table 1 are the quantities of a 20% nitrogen fertilizer to use in 100 gallons of water for each frequency of application and for various crops.

The range in nitrogen concentrations is relatively narrow across crops. For weekly application it ranges from 1 to 3 lbs. and for fertigation from 6 to 17 ounces of 20% nitrogen/100 gal. The conversion of ounces and pounds/100 gal. to ppm (parts per million) is quite simple when you realize that 1 oz. of 20% nitrogen in 100 gallons provides a 15 ppm solution of nitrogen and 1 lb. 20% nitrogen/100 gal. equates to 240 ppm nitrogen. The fact that a 20% nitrogen fertilizer was used for reference in Table 1 in no way implies that fertilizers with this concentration need to be used. A fertilizer containing 10% nitrogen may be used, but at twice the rate listed for a 20% nitrogen fertilizer.

The decision of which frequency to use for applying fertilizer is easily determined by the physical system of fertilizer delivery. A weekly system is warranted where the fertilizer proportioner must be moved about the greenhouse and connected to individual benches or zones one at a time. This would also be true where the concentrate capacity of the proportioner is small and necessitates stopping frequently to refill the tank. In these situations, fertilization requires considerably more time than watering; thus, the number of fertilizer applications should be minimized. A fertigation system would be more desirable in a firm where the proportioner is

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plumbed into the main water line and has a concentrate volume sufficient to handle the whole firm with one filling. With this set-up it is easiest to apply fertilizer all the time from every tap. To do otherwise would require flushing of lines between fertilizer and water applications and would require close monitoring of the proportioner valves to see that they are on or off at the appropriate times.

Table 1. Standard concentration requirements of fertilizers containing 20 percent nitrogen for several greenhouse crops*

Crop	Concentration Category	Concentration[1] (oz/100 gal) Weekly	Constant
Daffodil	None	-	-
Iris	None	-	-
Hyacinth	None	-	-
Tulip[2]	Very light	-	-
Snapdragon	Very light	16	6
Bedding plants	Very light	16	13.5
Elatior begonia	Very light	17	8.5
Azalea	Light	20	-
Gloxinia	Light	24	13.5
Rose	Moderate	32	10
Carnation	Moderate	32	13.5
Geranium	Moderate	32	13.5
Easter lily	Moderate	32	13.5
Chrysanthemum	Heavy	40	13.5
Poinsettia	Heavy	48	17

*From: Nelson, P. V. 1985. Greenhouse Operations and Management, 3rd ed. Reston Pub. Co., c/o Prentice-Hall, Inc. Englewood Cliffs, NJ.

[1] 13.5 oz. of 20 percent nitrogen fertilizer/100 gal (1 g/l) = 200 ppm nitrogen.

[2] As an insurance against nitrogen and calcium deficiencies calcium nitrate should be applied at the rate of 32 oz/100 gal (2.4 g/l) at the start and at the midpoint of the growth-room stages and at the start of greenhouse forcing.

Ratio of Nitrogen to Potassium

Having arrived at the frequency and rate of nitrogen to use, it is time to determine the amount of potassium needed. The ratio can range from 3 nitrogen : 1 potassium (K_2O) for azalea through 2 nitrogen : 1 potassium (K_2O) for begonia and up to 2 nitrogen : 3 potassium (K_2O) for carnations. All other crops are assumed to perform best with a 1 nitrogen : 1 potassium ratio.

The universality of a 1 nitrogen : 1 potassium ratio lends itself well to physical limitations in the plumbing system. If it were necessary to provide a different nutrient solution for each crop, excessive expenses would be incurred in the space required to house the concentrate tanks, the cost of the tanks themselves, and in the flushing of lines between application of different fertilizers.

The 1 nitrogen : 1 potassium ratio should be maintained until soil and leaf test results indicate that these two nutrients are out of balance. Upon this information,

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a correction should be made in the ratio and then eventually the 1:1 ratio should be resumed. In the event that the same imbalance occurs repeatedly over extended time, a permanent shift should be made in the nitrogen : potassium ratio.

Proportion of Phosphorus

Phosphorus may be provided exclusively as superphosphate at the time of root media preparation. See Table 2 for recommended rates. When no superphosphate, or less than the recommended rates, has been incorporated into root media, phosphorus should be applied regularly in the liquid fertilizer program.

Table 2. Quantities of single and treble superphosphate to use in soil based media and soilless media.

	Rate (lbs/yd^3)	
Phosphorus Source	Soil Based Media	Soilless Media
Single superphosphate	3.0	4.5
Treble superphosphate	1.5	2.25
plus gypsum	1.5	1.5

How much phosphorus should be included in the liquid fertilizer formulation when no superphosphate has been incorporated in the root medium? We know that the 1 nitrogen : 1 phosphorus (P_2O_5) : 1 potassium (K_2O) ratio of fertilizers such as 20-20-20 and 15-15-15 provides for more phosphorus than is needed. The amount of phosphorus in a 2-1-2 ratio such as 20-10-20 is more than adequate. Since research is lacking to state how low the phosphorus proportion can go it would be wise to adopt a 2-1-2 ratio.

Applications of more phosphorus than is needed rarely results in a phosphorus toxicity. The problem manifests itself in the tie-up of the micronutrients iron, manganese, zinc, and copper by excess phosphate. To compensate, extra quantities of micronutrients must be applied to the crop oversupplied with phosphorus.

Ammoniacal Nitrogen

At this point the frequency of application, concentration of nitrogen, and ratio of phosphorus and potassium to nitrogen is known. One more factor is important before developing the formulation. That is, the source of nitrogen.

Extra nitrogen taken up by plants as nitrate can safely be stored in root and shoot tissue as nitrate even at concentrations equal to one or more percent of the dry weight. However, when extra nitrogen is taken up as ammoniacal nitrogen it can only be stored safely at low concentrations measured in parts per million of plant dry weight. For chrysanthemum the upper critical threshold for ammoniacal nitrogen is 350 ppm (1). Urea sources of nitrogen behave similar to ammoniacal nitrogen because urea is converted to ammoniacal nitrogen either in the root medium by microorganisms or inside the plant by the enzyme urease.

High ammonium and/or urea containing fertilizers were not recognized in the past as a great problem when root media contained soil. Today in the soilless media ammonium toxicity is a prevalent problem. One possibility is a reduced conversion of ammonium to nitrate due to the lower pH level of soilless media. Conversion is best

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in a pH range of 7.0 to 8.0. Typically 20-20-20 fertilizers contain about 70% of their nitrogen in the ammoniacal plus urea form and the remainder as nitrate. In a soil-based medium (typically in the pH range of 6 to 7) the full impact of this level of ammoniacal nitrogen would not be felt since a sizeable portion would be converted to nitrate before plant uptake. Less ammoniacal nitrogen would be converted in the more acid soilless media; thus, the same 20-20-20 fertilizer would have the effect of a higher ammoniacal level.

Table 3. Quantities of fertilizer to dissolve in 100 gallons of water to make solutions containing nitrogen (N) and potassium (K_2O) each of 60 to 600 ppm concentration.

Fertilizer	% NH_4	Concentration of N and K_2O								
		600	480	360	240	200	150	100	75	60
		oz/100 gal								
20-20-20	70	40.2	32.2	24.1	16	13.3	10	6.7	5	4
15-15-15	52	53.4	42.7	32.0	21.3	17.7	13.3	8.9	6.7	5.3
20-10-20	40	40.2	32.2	24.1	16	13.3	10	6.7	5	4
ammonium nitrate +	36	17.4	13.9	10.4	7.0	5.8	4.4	2.9	2.2	1.7
potassium nitrate		18.0	14.4	10.8	7.2	6.0	4.5	3.0	2.3	1.8
(23-0-22)										
calcium nitrate +	0	36.0	28.8	21.6	14.4	12.0	9.0	6.0	4.5	3.6
potassium nitrate		18.0	14.4	10.8	7.2	6.0	4.5	3.0	2.3	1.8
(15-0-15)										
ammonium nitrate+	45	12.6	10.1	7.6	4.9	4.1	3.1	2.1	1.5	1.2
potassium nitrate+		18.0	14.4	10.8	7.2	6.0	4.5	3.0	2.3	1.8
diammonium phosphate		7.8	6.2	4.7	3.0	2.5	1.9	1.3	1.0	0.8
(21-10.5-21)										

Theoretically, high ammonium plus urea content fertilizers can be used in greenhouses if applied at the exact rate needed by the plant. Since it is nearly impossible to always know and regulate this amount excess will occur and ammonium toxicity may ensue. Fertilizers, therefore, should contain 50% or less ammonium plus urea. Some ammoniacal nitrogen is desirable since without it leaf and stem growth is not as extensive. Only a small amount of nitrogen, 15% or so, need be in the ammonium or urea form to achieve this growth stimulation. In northern states it is important to further reduce the ammoniacal nitrogen level during winter months to avoid plant injuries. This has not been the case in the warmer southern states.

Fertilizer Formulations

At this point the specifications have been drawn up for the required fertilizer. Three commercial formulations of fertilizer are presented in Table 3 along with the quantities of each required in 100 gallons of water to achieve various concentrations (ppm) of each. Note that the percent of nitrogen in the ammoniacal form (ammonium plus urea) is 70% in 20-20-20 but drops to 52% in a typical 15-15-15 formulation. This may explain why there is sometimes a different plant response to these two fertilizers even though they are used at appropriate rates to supply the same nitrogen concentration. The 20-10-20 PeatLite Special formulation contains 40% ammoniacal nitrogen. Nearly equal weights of ammonium nitrate and potassium nitrate provides a 23-0-22 formulation with 36% ammoniacal nitrogen. This is an excellent substitute for 20-20-20 where phosphorus has been provided as superphosphate in the root medium. Calcium nitrate and potassium nitrate in a 2:1 weight ratio provides a 15-0-15 formulation with no ammoniacal nitrogen. It makes a good 15-15-15 substitute where no

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phosphorus is needed. The combination of ammonium nitrate, potassium nitrate, and diammonium phosphate yields a 21-10.5-21 formulation with 45% ammoniacal nitrogen. This is a good 20-10-20 substitute and can be used where insufficient phosphorus was incorporated into the root medium.

The latter self-made formulations in Table 3 do not contain micronutrients or dye as the first three commercial formulations do. These can be simply added at a low cost by incorporating Compound 111 at the rate of 2.5 pounds per 100 pounds of fertilizer combination. The micronutrients without dye can also be included by adding 8 ounces of STEM per 100 pounds of fertilizer combination.

Table 4. Amounts of Fertilizer Carrier Sources to Combine When Making Various Fertilizer Formulas

Fertilizers		Nutrient Sources[1]											
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 per lb[3]	Reaction in Soil[4]
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[2]	21-53-0									x	0	16	SA
C'mum 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		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							95	15	B
Winter potash	15-0-22		1	1							96	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

* Adapted from: Koths et al. (1980).

[1] For names of fertilizer carrier sources see the first 9 entries in the Fertilizer Name column.

[2] Diammonium phosphate may be pelletized and coated. To dissolve, use very hot water and stir vigorously. Don't worry about sediment. Use crystalline potassium chloride if possible.

[3] Based on lowest available prices published by greenhouse supply firms.

[4] B = basic, N = neutral, SA = slightly acid, A = acid, VA = very acid.

Summary

When the preceding rules for drawing up fertilizer specifications are followed, what would otherwise be a difficult task becomes simplified. The value of this procedure is the ability it imparts to the grower to understand and carefully regulate nutrient availability to crops. The net result should be increased yield.

Literature Cited

1. Nelson, P. V. and K. Hsieh. 1971. Ammonium toxicity in chrysanthemum: critical level and symptoms. Comm. Soil Sci. Plant Anal. 2:439-448.

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