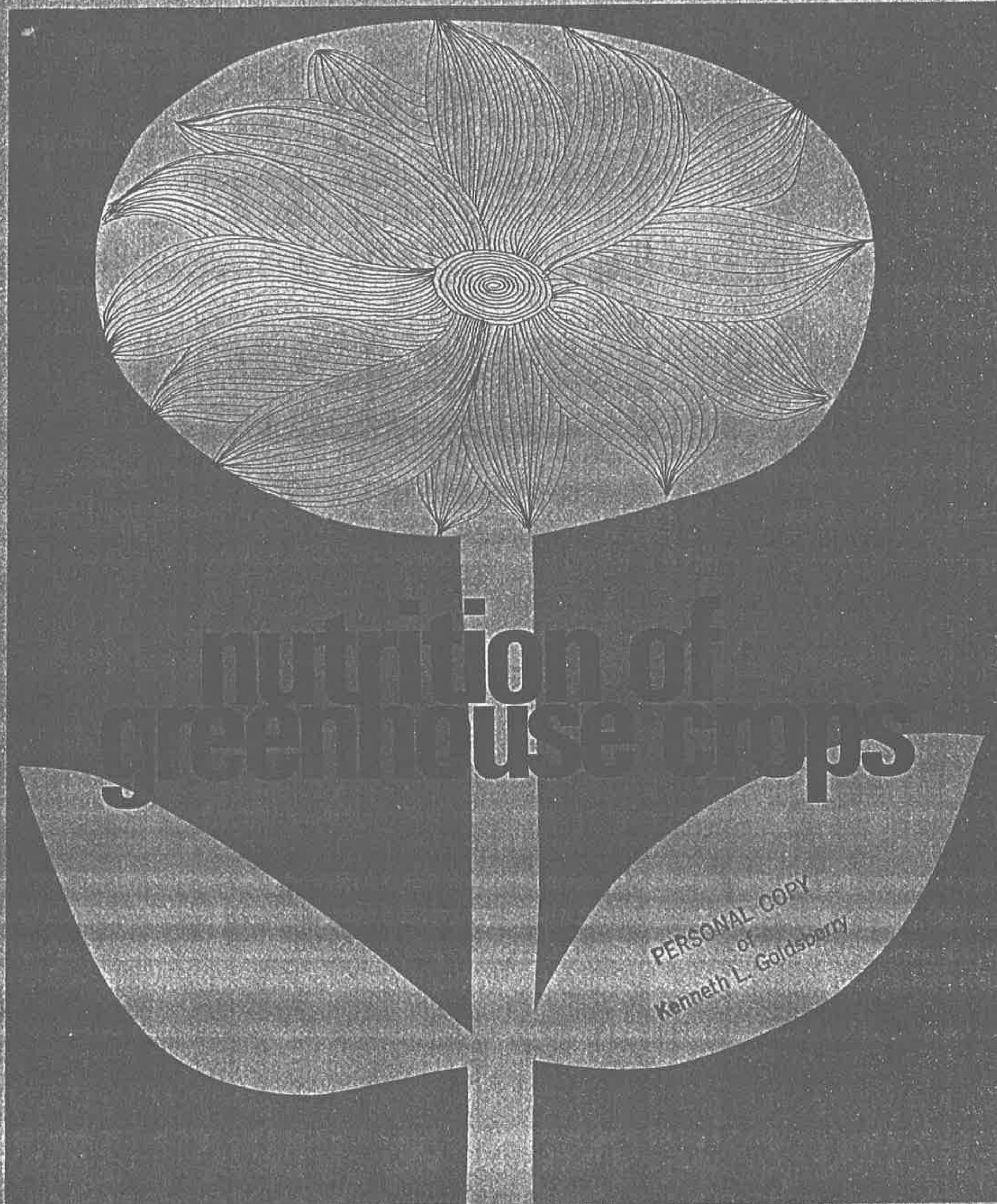
1987

304 76-14



nutrition of greenhouse crops

COOPERATIVE EXTENSION SERVICE
COLLEGE OF AGRICULTURE AND NATURAL RESOURCES, THE UNIVERSITY OF CONNECTICUT, STORRS

CONTENTS

Reprinted May 1977, UP, 3M

nutrition of greenhouse crops

Prepared by Connecticut Greenhouse Crop Production Task Force: *Jay S. Koths, Extension Floriculturist; Roy W. Judd, Jr., Extension Horticulturist; Joseph J. Maisano, Jr., Extension Agent – Horticulture; Gary F. Griffin, Extension Agronomist; John W. Bartok, Extension Agricultural Engineer and Richard A. Ashley, Extension Vegetable Specialist.*

FERTILIZER IS INEXPENSIVE. Less than 3% of the cost of producing a greenhouse crop is spent on fertilizer and application. Since fertilization costs so little in the production of a high-quality crop, ideal nutritional levels should be the goal of every grower.

With ideal nutrition, nutrients will not limit plant growth; the optimum growth for the plant will be limited only by other factors in the total environment.

Soil Testing

Soil testing is a valuable tool in determining your fertilizer program. It assists in obtaining optimum plant growth. The grower should look at soil testing

TABLE 1. SOIL TEST NUTRIENT AND SALT LEVELS

Soluble Salt Tolerances (1:2 soil-water extract)

Under 50:	usually indicated insufficient fertility
70-150:	normally fertile soils
100-120:	maximum for planting rooted cuttings or seedlings
150-200:	maximum for established crops

Plant Nutrient Levels for Established Crops in Parts Per Million (Spurway extraction)

	LOW	MEDIUM	HIGH	VERY HIGH	TOXIC
Ammonium N	2	2	5	10	Over 15
Calcium	Below 40	60-120	150	Over 200	----
Nitrate N	Below 5	10- 20	25- 50	50	Over 60
Phosphorus	Below 2	5	5- 10	10- 15	Over 15
Potassium	Below 10	20	30- 50	50	Over 60
Magnesium	Below 6 (or 1/10 of calcium)			Over 1/3 of Calcium	

Medium levels are suggested for establishing seedlings and rooted cuttings.
High levels are generally appropriate for established plants.

as a guide. It enables him to check the nutrient levels of his 'soil periodically and adjust his program accordingly.

Test your soil before the crop is planted. A soil sample representative of the planting area should be sent to the soils laboratory three to four weeks prior to planting. In this way, the results and recommendations can be used most effectively. Dry materials such as lime and superphosphate, if needed, can be incorporated in your preplanting preparation of soil. This will save time and labor. A fertilization program should be established for every crop. Sampling at regular intervals will indicate whether or not the program is correct and will help to determine any necessary changes.

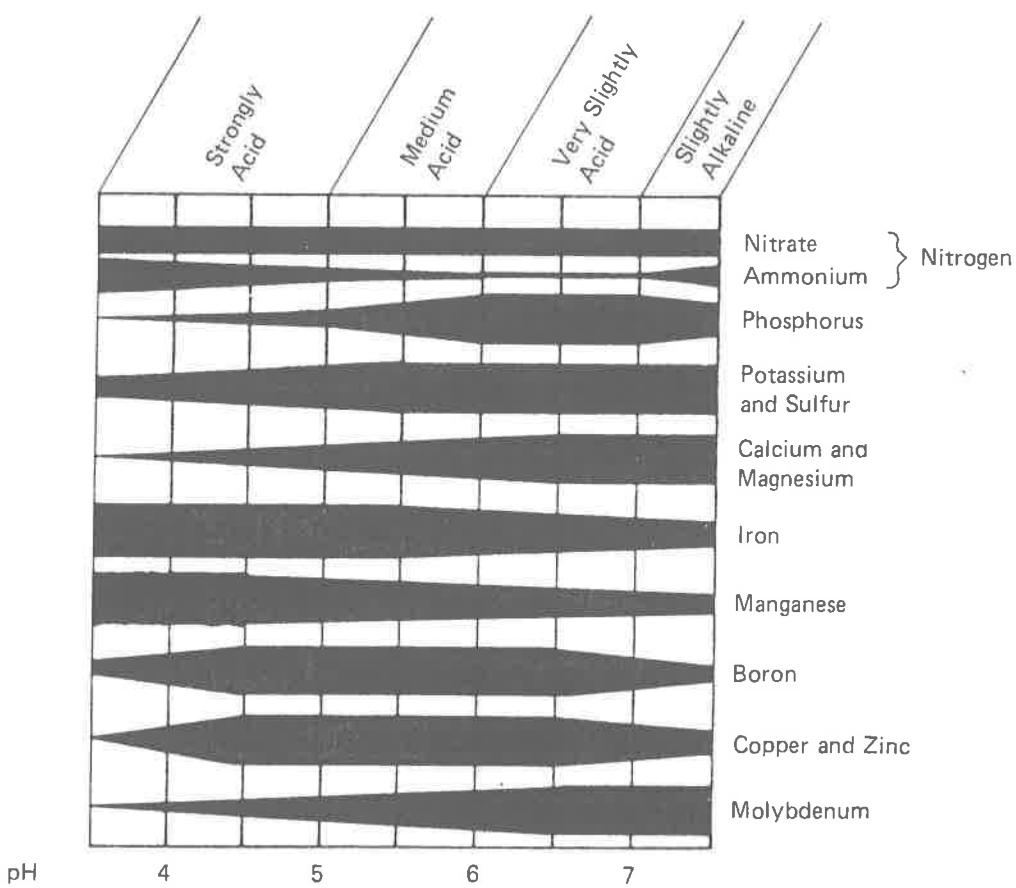
When dry fertilizers are applied to soil, the time of sampling for soil analysis may be important with regard to the nutrient levels obtained. With continual fertilization, sampling time is relatively unimportant. Nutrient levels do not oscillate as they do when fertilizers are applied less frequently but in greater quantities. Soil test mailers are available at your Connecticut Extension office for a nominal charge.

Limestone and Soil pH

The term pH means the degree of acidity or alkalinity of the soil. It is measured on a scale of 0-14 with 7 being neutral. Soils in Connecticut often have a pH of 4.5-5.0 and require substantial applications of limestone to overcome acidity. A lime requirement test may be made which will accurately measure the amount of limestone necessary to change an acid soil to a given pH, but this is not necessary since precise pH levels are not required. The following rule of thumb will suffice for many Connecticut greenhouse soils. **To move the pH level up 0.1 unit, use 1 lb. dolomitic agricultural limestone per 100 square feet or per cubic yard of potting soil mix.**

To illustrate this, a greenhouse bench with a pH of 5.5 would require 10 lbs. of dolomitic limestone per 100 square feet to raise the pH to 6.5. Many soils, especially those high in organic matter, require more limestone. For these, use a target pH of 7.0 rather than 6.5.

FIG. 1. AVAILABILITY OF PLANT NUTRIENTS IN GREENHOUSE SOILS.



There is more soil, of course, in 100 square feet of greenhouse bench than there is in a cubic yard, but more limestone is necessary when incorporated into a soil mix than when applied to the surface of a bench soil to obtain the desired change in pH.

Incorporating limestone into the soil does not change the pH of all the soil immediately. The pH of some greenhouse soils may rise slowly for weeks after such an application. But the pH of some areas in the soil will change as soon as the limestone becomes moist. In this case the root may be passing through zones differing widely in pH, absorbing the desired available nutrients from each zone as it passes through.

Hydrated lime is very dangerous in greenhouse soils. It is much more reactive than limestone. Ammonium nitrogen is absorbed on the soil complex and hydrated lime may displace it in quantities sufficient to damage roots. Hydrated lime also increases soluble salts, often to dangerous levels. Furthermore, the rapid change in soil pH is seldom desirable. In the few instances where a crop is detected growing in an extremely acid soil, hydrated lime may be suspended in water at 1 lb. per 5 gallons and applied at approximately 1 pint per square foot. This should be followed by an application of limestone to correct the pH, assuming that the hydrated lime will have raised the pH 0.5 units.

To reduce the soil pH, apply aluminum or iron sulfate at the rate of 1 lb. per 100 square feet to lower the pH 0.2 units. Elemental or wettable sulfur may be used at the rate of 1 lb. per 100 square feet per 1.0 unit.

Sphagnum peat moss is acid. The pH may vary from 3.0 to 4.5. As a general rule, 1 lb. of dolomitic limestone should be used for each cubic foot of peat as it comes from the bale. If the pH of the peat is below 4.0, increase limestone to 1¼ or 1½ lbs. per cubic foot.

The availability of many nutrients is affected by the pH of the soil (Fig. 1). The effects are sometimes not as pronounced in greenhouse soils as in field soils.

Most greenhouse crops grow best at pH 6.0-6.5. However, there are a few exceptions. The list (Table 3) is provided so that the correct pH may be chosen for the crop.

NITRATE NITROGEN is affected little by pH when applied frequently.

AMMONIUM NITROGEN may be more toxic in acid or alkaline soils than in nearly neutral soils. In acid soils the nitrifying bacteria are inhibited and cannot convert ammonium to the less toxic nitrate form. In alkaline soils ammonia gas, which is toxic to plants, may be liberated. This may also occur at a lower pH when hydrated lime is applied.

PHOSPHORUS is immobilized as ferric aluminum phosphates in acid soils. Incorporation of 0-20-0 at 5-7 lbs./cu. yd. will generally overcome this problem and supply adequate phosphorus for six months to a year.

POTASSIUM is more readily leached from acid soils but is otherwise affected little by pH changes.

SULFUR, applied generously as calcium sulfate in 0-20-0, is rarely limiting in greenhouse soils and is not seriously affected by pH.

CALCIUM and MAGNESIUM are adequately supplied in dolomitic limestone for plants grown at higher pH's in Connecticut soils. For crops that are grown in acid soils where these elements are readily leached, calcium sulfate (gypsum) and magnesium sulfate (Epsom salts) should be applied.

IRON is more soluble in acid soils. Some plants such as gardenias and azaleas cannot obtain sufficient iron at a higher pH although applications of chelated iron will temporarily provide available iron to the plant. Since iron reacts with phosphorus to form a rather insoluble precipitate, continuous fertilization with high phosphorus fertilizers may induce iron deficiency.

MANGANESE, like iron, is more available in acid soils. Except for highly organic or synthetic growing media where it should be incorporated, deficiencies seldom occur. Steaming soil renders manganese more soluble and toxicities may occur.

BORON is quite available at any pH below neutral. Consequently, it may become limiting in soils that are used for many years. Token applications made once or twice a year are suggested on carnations, snapdragons and some other crops unless manure is used.

COPPER is normally supplied from copper pipes in water systems and, as is ZINC, in pesticides. These metals are available at any pH below neutral and are seldom deficient. With the decrease in copper pipe usage, copper applications may become necessary.

MOLYBDENUM is unusual in that availability declines with acidity. It may be necessary to add trace amounts to crops grown in acid soils.

Phosphorus and Soil Preparation

Phosphates do not leach readily from soils. For this reason, superphosphate may be incorporated into the soil, before planting, in quantities sufficient to last

TABLE 2. ANALYSIS AND USE OF SOME COMMON FERTILIZER MATERIALS

	Name of Material	Analysis $N\text{-}P_2O_5\text{-}K_2O$	Other Nutrients Supplied	Rate of Application: Dry (lbs/cu yd)*	Rate of Application: Liquid (lbs/100 gals)	Speed of Reaction	Effect on pH
Primary Fertilizers	Ammonium sulfate $(NH_4)_2SO_4$	20-0-0	S	½-1 lb. per 100 sq. ft.	2-3	Rapid	Very Acid
	Sodium nitrate $NaNO_3$	15-0-0		¾-1¼ lb. per 100 sq. ft.	2 oz. per 2 gals.	Rapid	Basic
	Calcium nitrate $Ca(NO_3)_2.2H_2O$	15-0-0	Ca	¾-1½ lbs. per 100 sq. ft.	3 oz. per 2 gals.	Rapid	Basic
	Potassium nitrate KNO_3	13-0-44		½-1 lb. per 100 sq. ft.	2 oz. per 3 gals.	Rapid	Neutral
	Ammonium nitrate NH_4NO_3	33-0-0		¼-½ lb. per 100 sq. ft.	1¼ oz. per 5 gals.	Rapid	Acid
	Urea $CO(NH_2)_2$	46-0-9		¼-½ lb. per 100 sq. ft.	1-1¼ oz. per 5-7 gals.	Rapid	Sl. Acid
	Mono-ammonium phosphate $NH_4H_2PO_4$	12-62-0		1 lb. per 100 sq. ft.	2 oz. per 3 gals.	Rapid	Acid
	Di-ammonium phosphate $(NH_4)_2HPO_4$	21-53-0		½-¾ lb. per 100 sq. ft.	1¼-1½ oz. per 4-5 gals.	Rapid	Acid
	Treble superphosphate $Ca(H_2PO_4)_2$	0-40-0	Ca	1-2½ lbs. per 100 sq. ft.	Insoluble	Medium	Neutral
	Superphosphate $Ca(H_2PO_4)_2+CaSO_4$	0-20-0	Ca+S	3-8 lbs. (see text)	Insoluble	Medium	Neutral
	Potassium chloride KCl	0-0-60		½-¾ lb. per 100 sq. ft.	1¼-1½ oz. per 4-5 gals.	Rapid	Neutral
	Potassium sulfate K_2SO_4	0-0-50	S	½-1 lb. per 100 sq. ft.	Not advisable	Rapid	Neutral
	Urea formaldehyde	38-0-0		3-5 lbs. per 100 sq. ft.	Insoluble	Slow	Sl. Acid
Additives	Limestone, Dolomitic	None	Ca+Mg	5-20 lbs. (see text)	Insoluble	Slow	Basic
	Hydrated Lime $Ca(OH)_2$	None	Ca	2 lbs. per 100 sq. ft. (Not advisable)	Relatively insoluble (See text)	Rapid	Basic
	Gypsum (calcium sulfate) $CaSO_4$	None	Ca+S	2-5 lbs. per 100 sq. ft.	Insoluble	Medium	Neutral
	Sulfur	None	S	1-2 lbs. per 100 sq. ft.	Insoluble	Slow	Acid
	Epsom salts (magnesium sulfate) $MgSO_4.7H_2O$	None	Mg+S	8-12 oz. per 100 sq. ft.	1¼	Rapid	Neutral
	Aluminum sulfate, $Al_2(SO_4)_3$	None	S	1 tsp. per 6″ pot (not advisable)	20	Rapid	Very Acid
Complete	Complete soluble (mixtures)	20-20-20	Var.	Not advisable as dry	1½-2½ oz. per 3-5 gals. (See table 5)	Rapid	Various
		20-5-30	Var.				
		16-32-16					
	Complete dry (mixtures)	10-10-10	Var.	2 lbs. per 100 sq. ft.	Relatively insoluble	Various	Various
		5-10-10	Var.	2-3 lbs. per 100 sq. ft.	Relatively insoluble	Various	Various
	Organic	5-10-3	Var.	2-4 lbs. per 100 sq. ft.	Relatively insoluble	Various	Various
	Plastic coated pellets	Variable		See text	Insoluble	Slow	Various
	Magnesium ammonium phosphate	7-40-6	Mg	See text	Insoluble	Slow	Neutral
Organics	Activated sludge	Usually 5-4-0		3-5 lbs. per 100 sq. ft.	Insoluble	Medium	Acid
	Animal tankage	Usually 7-9-0		3-4 lbs. per 100 sq. ft.	Insoluble	Medium	Acid
	Castor pomace	5-1-1		3-5 lbs. per 100 sq. ft.	Insoluble	Slow	– – –
	Cottonseed meal	7-2-2		3-4 lbs. per 100 sq. ft.	Insoluble	Slow	Acid
	Dried blood	12-0-0		2-3 lbs. per 100 sq. ft.	Insoluble	Medium	Acid
	Hardwood ashes	0-1-5		3-10 lbs. per 100 sq. ft.	Insoluble	Medium	Basic
	Hoof and horn meal	13-0-0		2-3 lbs. per 100 sq. ft.	Insoluble	Slow	– – –
	Linseed meal	5-1-1		3-5 lbs. per 100 sq. ft.	Insoluble	Slow	Acid
	Seaweed (kelp)	Usually 2-1-15		2-3 lbs. per 100 sq. ft.	Insoluble	Slow	– – –
	Soy Bean meal	6-0-0		3-5 lbs. per 100 sq. ft.	Insoluble	Slow	– – –
	Steamed bone meal	Usually 3-20-0		5 lbs. per 100 sq. ft.	Insoluble	Slow	Basic
Trace	$MnSO_4$		S	3-6 oz. per 100 sq. ft.	– – –		
	$FeSO_4$		S	8-12 oz. per 100 sq. ft.			
	Chelated iron (8-12%)		Fe	1-2 oz. per 100 sq. ft.	¼		
	Borax		B	½ oz. per 100 sq. ft.	(See text)		
	$CuSO_4$		Cu+S	1-2 oz. per 100 sq. ft.	– – –		
	FTE		Many				

*These rates are also appropriate per 100 sq. ft. of bench.

TABLE 3. pH PREFERENCES OF GREENHOUSE CROPS

Greenhouse Crop	Use	pH Range	Optimum
African Violet	Pot Plant	6.0 - 7.0	6.5
Ageratum	Annual	6.0 - 7.5	6.5
Alyssum	Annual	6.0 - 7.5	6.5
Anemone	Cut Flower	6.0 - 7.0	6.5
Aster	Cut Flower	6.0 - 7.0	6.5
Astilbe	Pot Plant	6.0 - 7.5	6.8 - 7.2
Azalea	Pot Plant	4.5 - 5.5	5.0
Bachelor's Button	Annual	6.0 - 7.5	6.8
Balsam	Annual	6.0 - 7.5	6.8
Begonias	Annual/Pot Plant	5.5 - 7.0	6.5
Bromeliad	Pot Plant	6.0 - 7.0	6.5
Calceolaria	Pot Plant	6.0 - 7.0	6.5
Calendula	Cut Flower	6.0 - 7.5	6.5
Calla Lily	Cut Flower	5.5 - 7.0	6.5
Carnation	Annual/Cut Flower	5.5 - 7.0	6.5
Celosia	Annual	6.0 - 7.5	6.8
Christmas Cactus	Pot Plant	5.5 - 7.0	6.5
Chrysanthemum	Pot Plant/Cut Flower	6.0 - 7.0	6.5
Cineraria	Pot Plant	6.0 - 7.0	6.5
Coleus	Annual	6.0 - 7.5	6.5
Cyclamen	Pot Plant	5.5 - 7.0	6.0 - 6.5
Daffodil	Pot Plant/Cut Flower	5.0 - 7.5	6.0 - 6.5
Delphinium	Cut Flower	6.0 - 7.5	6.5
Foliage Plants (Green Plants)	Pot Plant	5.0 - 7.5	---
Fuchsia	Pot Plant	5.5 - 7.5	6.5
Gardenia	Pot Plant	4.5 - 6.5	5.0 - 5.5
Geranium	Pot Plant	6.0 - 7.5	6.5
Gerbera	Cut Flower	6.0 - 7.0	6.5
Gladiolus	Cut Flower	5.5 - 7.5	6.0 - 6.5
Gloxinia	Pot Plant	5.5 - 6.5	6.0
Hyacinth	Pot Plant	5.5 - 7.5	5.5 - 7.5
Hydrangea	Field Culture	5.0 - 6.0	6.5
	Pink & White	6.2 - 7.0	6.5
	Blue	5.0 - 5.5	
Iris	Cut Flower	5.0 - 7.0	5.5 - 6.5
Lantana	Pot Plant	5.5 - 7.5	6.5
Lobelia	Annual	6.0 - 7.5	6.5
Lilies	Pot Plant/Cut Flower	6.5 - 7.2	6.8
Marigold	Annual	6.0 - 7.5	6.8
Petunia	Annual	6.0 - 7.5	6.5
Phlox	Annual	5.5 - 7.0	6.2
Poinsettia	Pot Plant	4.5 - 7.5	4.8
Portulaca	Annual	5.5 - 7.5	6.5
Roses	Cut Flower	5.5 - 7.0	6.5
Salvia	Annual	6.0 - 7.5	6.5
Snapdragon	Annual/Cut Flower	5.5 - 7.0	6.0 - 6.5
Stock	Cut Flower	5.5 - 7.0	6.5
Tomatoes	Produce	5.5 - 7.5	6.5
Tulip	Pot Plant	5.5 - 7.5	6.0 - 7.0
Verbena	Annual	6.0 - 8.0	7.0
Zinnia	Annual	5.5 - 7.5	6.5

the duration of the crop or up to one year. Most greenhouse soils require about 5 lbs. of superphosphate (0-20-0) per 100 square feet per year. If the soil test shows over 10 ppm, it is not needed. When preparing a new soil mix, 5 lbs. per cubic yard may be sufficient but 8 lbs. may be required in some soils.

Superphosphate (0-20-0) contains about one-half gypsum ($CaSO_4$). Treble superphosphate (0-40-0 or 0-46-0) does not. Gypsum is desirable in Connecticut greenhouse soils as a general rule. If using 0-40-0, apply at one-half the rate recommended for 0-20-0 and apply an equal amount of gypsum.

If the potash is low when preparing soils, an application of 8 oz. muriate of potash per cubic yard may be included.

Composting Soil for Greenhouse Use

Soil formulas are frequently written as 3(compost):2(peat):1(sand). The compost designation for the first component is frequently looked upon by many greenhouse operators as being satisfied by any old field soil that can be obtained. This is the weak link in many soil mixing programs. A little thought in the preparation of the "compost" fraction of your soil mix may be more important than the careful balancing and blending of the components during the mixing process.

The time-honored method of composting soil consists of laying down alternate layers of sod soil and manure. Limestone is spread on top of each layer of soil and superphosphate on top of each layer of manure. The top of the pile is dished to catch the water, and during dry periods the pile is watered to maintain moisture and accelerate decomposition of the manure. If built in June, kept moist, and sliced and turned in August, the pile should be ready for use in September. With machines to facilitate handling and turning, more growers might consider building compost piles.

With the growing scarcity of manure in some areas, other types of organic matter are often substituted. If leaves are used composting may require a year or more. Leaf composting operations sponsored by many towns provide an excellent source of organic matter. For best results, recompost with soil for a few months.

Field preparation of soil may be more efficient than a pile. In this method, topsoil is stockpiled flat on the ground so that it may be worked with power equipment. Limestone and superphosphate are spread. Organic matter and/or manure is distributed on top, then rototilled or worked into the soil. After suitable decomposition, this may be gathered with a bucket loader and stockpiled for winter use.

The Numbers on the Fertilizer Bag

Most fertilizer analyses contain three numbers. The first number indicates the percentage of elemental nitrogen (N). The second number indicates the percentage of phosphorus in the oxide form (P_2O_5). Actually, most of the phosphorus exists in the phosphate (PO_4) form. The third number stands for potassium, expressed as the oxide (K_2O). The potassium ion is always combined with some other element such as chlorine in potassium chloride (muriate of potash). These three, along with calcium, magnesium and sulfur, comprise the six macronutrients.

The ratio means the balance between these nutrients. For example, the 20-20-20 grade represents a 1:1:1 ratio – meaning equal amounts of nitrogen, phosphate and potash.

The percentage of each nutrient in a fertilizer is carefully regulated, and manufacturers are licensed. Samples are periodically analyzed by government laboratories to make certain that the label is correct.

There is a possibility that within a few years, the fertilizer analyses will be reported in terms of N, P and K instead of the oxides. This will not change the nitrogen percentage but the phosphorus and potassium numbers will be smaller. Since both analyses will probably be printed on the bag for a period during the change-over to the new numbering system, this should not be confusing.

Some fertilizer analyses contain a fourth number. This usually stands for magnesium content. Since most of the limestone available in this section of the country is dolomitic limestone and contains a high proportion of magnesium, this type of fertilizer is not generally recommended for greenhouse use.

Simplified Fertilizer Mixing

What would happen to the formula for muriate of potash if you mixed it with an equal amount of sand? Instead of an 0-0-60, the potash would be diluted so that the mixture would be an 0-0-30.

Then what would happen if you diluted it with ammonium nitrate (33-0-0) instead of sand? Each fertilizer would dilute the other so that you would

TABLE 4. FERTILIZER WEIGHT AS MEASURED BY STANDARD POT SIZE

Fertilizer	2¼"	3"	3½"	4"	5"	6"
Cottonseed meal	2 oz.	5½ oz.	8½ oz.	14 oz.	1 lb. 10 oz.	2 lb. 12 oz.
Electra, 5-10-3	2 oz.	5½ oz.	9 oz.	15 oz.	1 lb. 12 oz.	2 lb. 14 oz.
Ammonium nitrate	2 oz.	5½ oz.	9 oz.	15 oz.	1 lb. 12 oz.	2 lb. 15 oz.
Urea, 45-0-0	2½ oz.	6 oz.	9 oz.	1 lb.	1 lb. 13 oz.	3 lb.
Superphosphate	2½ oz.	6 oz.	9½ oz.	1 lb.	1 lb. 14 oz.	3 lb. 2 oz.
Dusting sulfur	2½ oz.	6 oz.	10 oz.	1 lb.	1 lb. 14 oz.	3 lb. 3 oz.
Peters, 20-5-30	2½ oz.	6 oz.	10 oz.	1 lb. 1 oz.	1 lb. 15 oz.	3 lb. 3 oz.
UConn Mix, 19-5-24	2½ oz.	6½ oz.	10 oz.	1 lb. 1 oz.	2 lb.	3 lb. 5 oz.
Ammonium sulfate	3 oz.	7 oz.	11 oz.	1 lb. 3 oz.	2 lb. 3 oz.	3 lb. 11 oz.
Osmocote, 14-14-14	3 oz.	7½ oz.	12 oz.	1 lb. 4 oz.	2 lb. 5 oz.	3 lb. 13 oz.
MagAmp, 12-62-0	3 oz.	7½ oz.	12 oz.	1 lb. 4 oz.	2 lb. 5 oz.	3 lb. 14 oz.
Gypsum, $CaSO_4$	3 oz.	8 oz.	12½ oz.	1 lb. 5 oz.	2 lb. 7 oz.	4 lb. 1 oz.
Calcium nitrate	3 oz.	8 oz.	12½ oz.	1 lb. 6 oz.	2 lb. 8 oz.	4 lb. 2 oz.
Peters, 15-0-15	3½ oz.	8 oz.	13 oz.	1 lb. 6 oz.	2 lb. 9 oz.	4 lb. 5 oz.
Potassium chloride	3½ oz.	9 oz.	14 oz.	1 lb. 8 oz.	1 lb. 12 oz.	4 lb. 9 oz.
Sodium nitrate	4 oz.	9 oz.	15 oz.	1 lb. 9 oz.	2 lb. 14 oz.	4 lb. 13 oz.
Dolomitic limestone	5½ oz.	13 oz.	1 lb. 5 oz.	2 lb. 4 oz.	4 lb. 2 oz.	6 lb. 14 oz.

Clay flower pots are frequently used for fertilizer measurement by greenhouse operators. The above shows average weights of several representative fertilizers as measured by standard clay pots when level full. The 3-inch standard is considered to contain 8 fluid ounces, or one cup. Since the actual pot size varies with the manufacturer and the volume of a given weight of fertilizer varies with moisture and compaction, deviations of 10% may be expected but up to 40% may occur.

have a 16-0-30. A convenient way to obtain this is to add the formulas in columns and divide by the number of fertilizers used.

Muriate of potash	0-0-60
Ammonium nitrate	33-0-0
	33-0-60 ÷ 2 = 16-0-30

This procedure works with any number of components. Let's mix one part of ammonium nitrate, urea, di-ammonium phosphate and two parts muriate of potash.

Ammonium nitrate	33-0-0
Urea	45-0-0
Di-ammonium phosphate	21-53-0
Muriate of potash	0-0-60
Muriate of potash	0-0-60
	99-53-120 ÷ 5 = 20-10-24

This is a good all-purpose fertilizer for greenhouse use and will cost about 12 cents a pound. But since most of the nitrogen is in the ammonium form, this formula should be used primarily during warm months on soils that have not been recently pasteurized. A fertilizer of similar ratio that contains over half nitrate nitrogen (it is used in the UConn greenhouses) can be made in the following manner:

Potassium nitrate	13-0-44
Potassium nitrate	13-0-44
Potassium nitrate	13-0-44
Potassium nitrate	13-0-44
Potassium nitrate	13-0-44
Potassium nitrate	13-0-44
Urea	45-0-0
Urea	45-0-0
Calcium nitrate	15-0-0
Calcium nitrate	15-0-0
Monoammonium phosphate	12-62-0
	210-62-264 ÷ 11 = 19-5.6-24

When you mix equal parts, the size of the part is not important. When mixing large quantities, dump entire bags on a clean floor, mix with a shovel and place back in the bags, labelling correctly. Or better yet, prepare small plastic bags of a size appropriate for your injector. The mixture may not be completely uniform, but it is unlikely that the error will be greater than 10%. The inaccuracies are cancelled out as subsequent feedings are given. Formulas for mixing many soluble fertilizers, along with directions for use, are given in Table 5.

Fertilizer Injection

The rate of nutrient uptake by the plant is closely correlated with water use. The development of efficient fertilizer proportioners enables the grower to inject fertilizer into the water system. This is called continual fertilization. Rates are given in Table 5.

Saving labor is the most obvious advantage of continual fertilization, but better plant growth is a more important factor. Soluble salt problems are often reduced. Proper soil management combined with the use of dry fertilizers is necessary to maintain the effectiveness of continual fertilization.

Even with the addition of micronutrients, the improvement in growth noted in the beginning of a continual fertilization program may not persist. The addition of an organic fertilizer, preferably a complete one, will help maintain maximum productivity. For example, on carnations benched in June, a complete organic fertilizer could be applied at about 2 lbs. per 100 square feet in late July and again in September and March. On chrysanthemums, an organic feed should be given four or five weeks after benching except in midwinter. Don't use any one fertilizer exclusively on long-term crops.

Injectors should be checked occasionally to make certain that they are accurate. Place the suction tube in a gallon container. Deliver exactly 10 gallons of water. Measure the liquid necessary to replenish the stock container. This should correspond to the calibration column in Table 6.

Calculating Parts Per Million

There are many methods for calculating fertilizer concentrations in parts per million (ppm). Since 1 oz. of material in 100 gallons of water is equal to 75 ppm, this is simple to calculate.

For instance, the summer continual fertilization rate is based on 150 ppm of nitrogen. Since 1 oz. = 75 ppm, 2 oz. will = 150 ppm. Now suppose that we are using a 20-4-20. This contains 20% (1/5) nitrogen. Since it is only 1/5 nitrogen, 5 oz. will be required to supply 1 oz. of nitrogen. So 10 oz. of 20-4-20 will be required to supply 2 oz. of nitrogen which when dissolved in 100 gallons will give 150 ppm.

This procedure may be reversed to find the concentration of a fertilizer solution. For example, 20-5-30 is recommended at 1 lb. per 40 gals. as a full strength liquid feed. This equals 2½ lbs. or 40 oz. per 100 gals. 40 oz. x 75 = 3000 ppm fertilizer. 3000 x 20% = 600 ppm nitrogen, or about 4 times the continual fertilization rate. At the same time, P_2O_5 = 3000 x 5% = 150 ppm and K_2O = 3000 x 30% = 900 ppm.

Calibrating the Gewa Proportioner

The magic number is 300. Divide 300 by the number on the selector switch – the result is the number of gallons of water mixed with each gallon of stock solution.

Why did the manufacturer mark the selector in this way? If the stock solution is prepared with 3 lbs. of

TABLE 6. PREPARING FERTILIZER STOCK SOLUTIONS

Fertilizer Injector	Injection Ratio	Fertilizer Application Rate: Lbs./100 Gallons						Calibration Factor*
		1	1¼	1½	2	2½	3	
		Ounces per gallon of stock						
Hozon	1:15	2.4	3	3.6	4.8	6	7.2	85
Hydrocare	1:24	3.8	4.8	5.8	7.7	9.6	11.5	53
– – –	1:60	9.6	12	14.4	19	24	28.8	21
– – –	1:75	12	15	18	24	30	36	17
Smith, Gewa, MP	1:100	16	20	24	32	40	48	12.8
Commander	1:128	20	25	31	41	51	NA	10
Gewa	1:150	24	30	36	48	NA	NA	8.5
Smith or MP	1:200	32	40	48	NA	NA	NA	6.4
– – –	1:300	48			Not advisable			

This chart gives the number of ounces of fertilizer to be added to each gallon of stock solution for fertilization rates of 1 to 2½ lbs. per 100 gallons.

**This column shows the ounces of stock depleted when 10 gallons of water are metered through the injector.*

TABLE 5. FORMULATING AND USING SOLUBLE FERTILIZERS

Formula Name		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. (a)	Reaction in soil (b)	Continual fertilization rate (c) oz/100 gals.	Full strength (600 ppm N) lbs/100 gals	Hozon oz/gal stock	Azalea	Bedding plants	Carnations	Chrysanthemums	Geraniums	Hydrangea (d)	Lily	Poinsettia	General
Ammonium nitrate	33-0-0	x									50	12	A	—	1¼	3									
Potassium nitrate	13-0-44		x								100	18	N	—	2	5			x	x	x		x	x	x
Calcium nitrate	15.5-0-0			x							94	13	B	—	2½	6							x		
Sodium nitrate	16-0-0				x						100	10	B	—											
Ammonium sulfate	21-0-0					x					0	5													
Urea	45-0-0						x				0	14	SA	—	1	2									
Potassium chloride	0-0-60							x			—	8	N	—	1 2/3	4									
Monoammonium phosphate	12-62-0								x		0	34	A	—	NA	NA									
Diammonium phosphate	21-53-0									x	0	16	SA	—	NA	NA									
C'mum green	18-0-22	1	2			1					53	14	A	11	2½	6				x					
General summer	20-10-24	1					1	2		1	17	12	A	10	2½	6	x	x		x	x				x
General low phosphate	21-4-20	7						4		1	45	12	A	10	2½	6	x							x	x
General summer	21-17-20	1					2	3		3	10	12	A	10	2½	6	x			x	x				
General	17-6-27							4		1	43	11	A	12	3	7	x	x	x	x	x				x
UConn Mix	19-5-24		6	2			2		1		51	18	N	10½	2½	6	x	x	x	x	x	x	x	x	x
Editor's favorite	20-5-30		13				4			2	43	17	SA	10	2½	6		x	x	x	x	x		x	x
20-20-20 substitute	20-20-22		4				1			3	33	17	SA	10	2½	6		x				P			x
Starter	12-41-15		1						2		35	29	SA	10	2½*	6		x				P			
Starter	17-35-16						1	4		10	0	14	SA	10	2½*	6		x				P			
N-K only	16-0-24	2			1			2			60	10	SA	12½	3	7			x	x					
N-K only	20-0-30	1	2								72	16	SA	10	2½	6			x	x				x	x
Blue Hydrangea	13-0-22					2		1			0	6	VA	15	2½*	7						B			
Blue Hydrangea	15-0-15					3		1			C	6	VA	13	3*	7						B			
Acid	21-9-9	3	1			7		1		2	21	10	VA	10	2½	6	x								
Spring carnation	11-0-17				5			2			100	10	B	16	3*	7			x						
Winter nitrate	15-0-15		1	2							95	15	B	13	3*	7		x		x	x		x	x	x
Winter potash	15-0-22		1	1							96	16	B	13	3*	7		x	x	x	x		x	x	x
Lily substitute	16-4-12	1	4	6						1	78	15	N	12½	3*	7							x	x	
High K	15-10-30		7	1						2	72	17	N	13	3*	7			x	x					

Di-ammonium 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.

(a) Based on lowest available prices published by greenhouse supply firms.
(b) B = basic, N = neutral, SA = slightly acid, A = acid, VA = very acid.
(c) These rates provide about 150 ppm nitrogen. During December, January and February, this concentration should be increased by 1/3 to provide 200 ppm N, preferably in nitrate form.
(d) P = pink, B = blue – hydrangea.

**This full strength feed rate supplies less than the normal 600 ppm N.*

fertilizer per gallon (18 lbs. per 6 gallon Gewa), the selector indicator will show the number of pounds of fertilizer per 100 gallons of water.

For instance, placing 3 lbs. of 20-5-30 in a gallon of stock will provide 3 lbs./100 gallons at position 3 (300 ÷ 3 = 100 gallons of diluted fertilizer solution). If placed on position 2, it will deliver 2 ibs./100 gals. (300 ÷ 2 = 150 gallons diluted fertilizer solution containing 1 gallon of 3 lbs. stock solution, or 2 lbs. per 100 gallons).

Since many of our recommendations are expressed as pounds per 100 gallons, dissolve the desired weight of fertilizer in each gallon of stock and set the selector at 3.

For example, if the recommended rate is 2½ lbs. per gallon, place 2½ lbs. in each gallon of stock (15 lbs. per 6 gallon Gewa) and set the selector switch at position 3.

Dyes

Dyes may be added to your fertilizers as visual guides to make certain that your injector is working properly. These are used at the rate of about 1 teaspoon per 1000 gallons of diluted fertilizer solution. Various colored dyes may be used to color code different fertilizer formulas. They may be obtained from the following companies:

Bachmeier & Co., Inc., 154 Chambers Street, New York, N.Y. 10007

Dupont Dyes and Chemicals Division, 7 South Dearborn St., Room 1626, Chicago, Ill. 60603

Robert B. Peters Co., 2833 Pennsylvania Street, Allentown, Pa. 18104

Slater Supply Co., Inc., 416 S. Cherry Street, Wallingford, Conn. 06492

Slow Release Fertilizers

SRF have attracted much attention in the past few years. The most popular are Osmocote, ureaform and MagAmp. These materials provide nutrients over a period of time. All are generally incorporated in the soil mix although Osmocote is often topdressed. None of these have consistently provided complete nutrition for an entire crop.

These are best used at reduced rates in connection with supplemental liquid fertilization. Appropriate rates are 4-5 lbs./cu. yd. of Osmocote 14-14-14 or 3 lbs./cu. yd. MagAmp. When using MagAmp, also incorporate 2 lbs. gypsum to overcome the suppression of calcium availability. Do not incorporate Osmocote before steaming or more than 7 days prior to use. The higher recommended rates may be appropriate for other areas of the country but have been found to be excessive in many instances in Connecticut.

Preventing Backflow from Your Fertilizer Injector

All potable water systems must be protected against backflow to insure that contaminated water is not mixed with water that is used for human consumption. Backflow or backsiphoning occurs when a negative pressure develops causing water that has been contaminated to be drawn back into the supply lines.

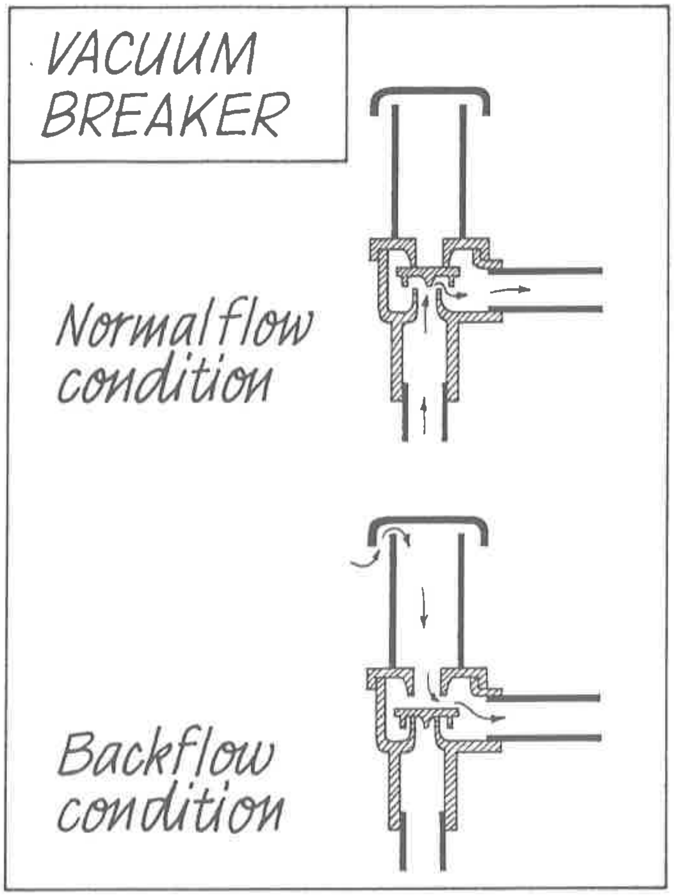
The National Plumbing Code which has been adopted in most states requires that backflow preventers be installed on any supply fixture which has an outlet end which may be submerged. Some examples are: a hose that fills a spray tank or barrel, a fertilizer injector, and an equipment washtub.

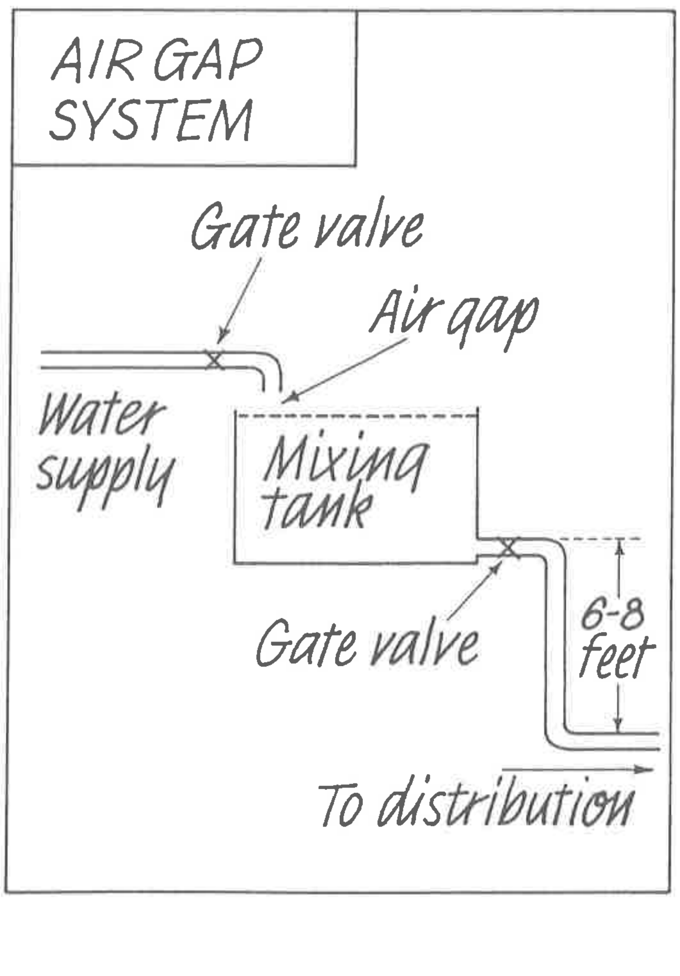
The most commonly used backflow preventer is the vacuum breaker. It is a combination check valve and air relief valve in one integral unit. If the pressure in the water supply lines drops below a predetermined level, the check valve will close and shut off the water supply. With the check valve in the closed position, the air relief part of the unit is open, allowing air to enter the system which breaks the vacuum created by the negative pressure in the supply lines and prevents backflowing of the water into the potable water supply. This type of valve should be installed between the last control valve of the supply system and the fixture being served. For example, the vacuum breaker should be installed just prior to the intake to a fertilizer injector.

In low pressure watering systems (less than 5 psi) an elevated mixing tank is sometimes used to supply water to the drip tubes or trickle hose. Fertilizer is often mixed in the water to supply nutrients to the plants. A space equal to at least twice the diameter of the supply pipe is required between the outlet of this pipe and the highest possible water level in the tank. This air gap provides positive protection against backflow.

If you are supplied by a municipal water system, check the local regulations prior to installation as some companies require a complete break in the water system. If this is the case, a separate pump and supply tank will be required.

Public Health Service Drinking Water Standards and the National Plumbing Code prohibit cross-connections and interconnections between potable





and nonpotable water systems. An example of this type of connection is where pipes are connected so that water can be supplied to a greenhouse from either a well, pond or stream, depending on which valve is open. Another example is where a water system is connected so that either municipal water or water from a private system supplies the greenhouse. These types of systems are dangerous, as valves may leak or may be inadvertently left open. All cross-connections and inter-connections between potable and nonpotable water systems should be eliminated.

Measuring Water

Proper watering should provide 10% more water than is necessary so that leaching will reduce salts, and good fertilizer distribution will occur.

The amount of water necessary to provide this 10% leaching may be approximated by dividing the soil depth in inches by 15. For example, 6 inches ÷ 15 = 0.40 (2/5) gallons per square foot.

Here is a handy formula to determine the amount of water necessary to thoroughly water a bench and provide 10% leaching. Multiply the bench area (in square feet) by the depth of soil (in inches) and divide by 15.

$\frac{(\text{sq. ft. bench})\times(\text{depth in inches})}{15}$ = number gallons required per bench to give 10% leaching.

This formula is appropriate for light greenhouse soils. For heavier soils, divide by 12 instead of 15.

Timing Water Application

To calculate the time necessary to water a bench with a hose, turn the hose on just as though you were watering. Time the number of seconds required to fill a 5-gallon pail. Next, measure the bench area (a 42" bench 90 feet long equals 315 square feet). Now multiply the time in seconds by the number of square feet.

This number when divided by:
600 = minutes to apply .50 gal. per sq. ft.
700 = minutes to apply .43 gal. per sq. ft.
750 = minutes to apply .40 gal. per sq. ft.
800 = minutes to apply .37 gal. per sq. ft.
900 = minutes to apply .33 gal. per sq. ft.
For those of you who like a formula, here it is:

$\frac{txs}{800}$ = T, where

t = time in seconds to run 5 gallons
s = square feet of bench
T = time in minutes to deliver .37 gals./sq. ft.

DEFICIENCY SYMPTOMS OF SOME PLANT NUTRIENTS

Plant	Nitrogen — N	Phosphorus — P	Potassium — K
Azalea	Pale green leaves, red color, poor branching.	Slow, dark green growth, poor bud set.	Slow growth, premature dropping of old leaves.
Bedding Plants	Leaves and plants yellow and small.	Leaves dark green, may turn purple with tip burn.	Tips of older leaves chlorotic; may spread over entire leaf.
Begonia semperflorens	Slow, pale growth; leaves and stems of colored cultivars turning red.	Growth stunted, no branching.	Necrosis on leaf margins, later turn brown and shed.
Calceolaria and Cineraria	Older leaves yellow-green.	Slow, dark green growth.	Young leaves yellow-green, older leaves show large necrotic spots, turn brown or black.
Carnation	Light color, small flowers, lack of "pig-tail" curl of leaf tips and foliage bloom.	Slow, dark green growth.	Lower leaves turn brown and die, increased susceptibility to disease, weak stems in midwinter.
Chrysanthemum	Pale green color contrasting with blue-green of high levels of nitrogen, leaves and flowers small.	Slow, dark green growth.	Leaves become gray-green; slow growth, chlorosis of margins of lower leaves progressing rapidly to necrosis.
Geranium	New growth lighter green; red margins and veins may develop on older foliage, especially at lower temperatures.	Slow, dark green growth, delay in flowering; margins may curl up.	Chlorosis of interveinal areas and margins of lower leaves. New growth may appear dull.
Gloxinia	Smaller leaves, not as dark green.	Slow growth.	Browning of oldest leaves.
Hydrangea	Pale green, smaller leaves.	Not generally found in normal forcing. Young stock may have reduced flower buds.	Marginal necrosis of lower leaves. May be severe and progress to upper leaves. May be confused with hydathode salt burn.
Lily, Easter	Little color change but leaves may be smaller and plants taller.	Not generally found in normal forcing.	Not frequently observed. Premature death of lower foliage, especially when plants are crowded.
Poinsettia	Uniform light yellow-green color, more severe on older leaves, slow growth.	Dark green, slow growth, plants stunted, older leaves yellow followed by necrosis.	Chlorosis of interveinal areas of old leaves progressing to necrosis and advancing up the plant.
Rose	Pale green, smaller leaves, increase in blind wood, older leaves may turn bright yellow.	Slow, dark green growth, increase in blind wood, old leaves drop green.	Early loss of older leaves sometimes accompanied by marginal chlorosis, weak stems.
Seedlings	Turn yellow as soon as seed reserves are exhausted.	Slow growth. Seedlings require adequate phosphorus.	Not as critical as N and P.
Snapdragons	Pale green to yellow, small leaves, fewer flowers and side branches. Leaves may bend down.	Slow, dark green growth with younger leaves rolling inward.	Yellowing of lower leaves reduced growth. May induce Fe deficiency on young leaves with reddish tinge on margins.
General	Pale green to yellow color, older leaves first, often accompanied by red, bronze or purple pigment accumulation, slow growth.	Slow growth often accompanied by purplish pigmentation and darker green foliage. Poor bud or flower formation.	Marginal and interveinal chlorosis beginning on oldest leaves. Reduced resistance to disease.

Calcium — Ca	Magnesium — Mg	Sulfur — S	Iron — Fe
Slow growth, poor root activity. Terminal bud abortion.	Seldom found. Older leaves exhibit interveinal chlorosis and drop prematurely.	Seldom found.	Chlorosis of new leaves, symptomatic or poor root activity or high pH.
Stunted growth, poor roots.	Interveinal chlorosis, premature defoliation.	Pale green leaves, particularly young ones.	Interveinal chlorosis on new growth.
Terminal growth stunted; leaves light green with red margins; poor roots.	Interveinal chlorosis followed by necrosis.	Slow growth, leaves dull grayish yellow.	Terminal chlorosis with green veins.
Slow growth, poor roots.	Interveinal chlorosis of older leaves progressing upward.	Slow growth and chlorosis of young leaves.	Interveinal chlorosis of terminal leaves, symptomatic of root damage.
Slow growth, poor root activity; tip burn on young leaves and calyces, sleepy flowers.	Mid-leaves chlorotic with green midribs.	Slow growth, upper leaves become yellow, flowers develop slowly, stems stiff.	Deficiency seldom seen, nutrient requirement low.
Slow growth, terminal buds and leaves may die; poor root activity.	Interveinal chlorosis of newly mature leaves, veins remaining quite green.	Slow growth, upper leaves becoming yellow, veins lighter, tips darker.	Growing tips become yellow to white. Veins remain green longer than interveinal areas.
Slow growth, red pigment at lower temperatures, especially if nitrogen is also low. Poor roots.	Interveinal chlorosis of newly mature leaves. Seldom a problem.	Light green foliage, reduced growth, especially of terminals.	Young leaves chlorotic with veins which may turn white.
Seldom found.	Seldom found.	Seldom found.	Seldom found.
Not generally found in normal forcing.	Interveinal chlorosis of newly mature leaves, especially when grown as pink.	New growth light green, more susceptable to mildew.	Chlorosis of youngest leaves, green veins, more common during juvenile growth.
Poor root activity, lower bud count; bud split just prior to opening.	Not generally found in normal forcing.	Not generally found.	Not generally found.
Slow growth sometimes resulting in bud stoppage and poor bract formation, root activity may be poor.	Interveinal chlorosis of newly mature leaves forming a pyramid design around midrib.	Yellowing of topmost leaves.	New leaves chlorotic with green veins, symptomatic of root damage.
Slow growth, poor root activity, increase in blind wood, or terminal growth abortion.	Interveinal chlorosis of older or newly mature leaves.	Slow growth, upper leaves turning yellow. Seldom observed.	Interveinal chlorosis of new growth, symptomatic of poor root activity.
Seldom limiting.	Seldom limiting.	Almost never limiting.	Almost never limiting.
Poor root activity. May induce Fe deficiency. Bud abortion possible.	Cupping of upper leaves, white necrosis along veins or in small interveinal spots.	Upper leaves become mottled yellow, principle vein turning white on more mature leaves. Flowers pale.	Interveinal chlorosis giving striped effect.
Terminal growth stunted, bud abortion, poor root activity.	Interveinal chlorosis of newly mature or older leaves.	Yellowing of upper leaves, sometimes with lighter veins and reduced growth.	Interveinal chlorosis of youngest leaves, veins slowly becoming white. (In Mn deficiency, veins remain green.)

Remember, 1/3 (.33) gallon may be sufficient for some light soils. A normal watering is more likely to be 2/5 (.40) gallons per square foot.

Soluble Salts

The soluble salt level, as determined by the Solu-Bridge, is a measure of the electrical conductivity of a soil-water mixture. Salts are derived from fertilizers, manure, water, and many other sources. Excessive levels are detrimental to plant growth.

To remove most of the salts from a soil, five gallons of water per square foot should be applied. Visualize this by picturing a 5-gallon can sitting on the bench and all of the water in it passing through the soil below it.

The water should be applied in one continuous operation to avoid problems. Applying in two operations is not advisable even though soaking the soil for some time may permit some salts to dissolve for removal by the second leaching. When the water is applied in one leaching rather than in two separate leachings, more water is required. When leaching with 3 to 5 gallons of water per square foot, perhaps 10% more water is required to remove the same amount of soluble salts. The cost of this additional water is insignificant in comparison to the damage which may occur from two lighter, separate leachings and the additional labor cost of two leaching operations.

The detrimental effects of double leaching generally fall in two classifications – structure and aeration. Oxygen levels are reduced in soil when water is applied since air is displaced by the water. Respiration by microbes, insects and plants uses some of the oxygen which remains. The reduction of oxygen is intensified since the soil channels are filled with water and diffusion of new oxygen into the soil is reduced.

Since leaching is more effective over a longer period of time, trickle-type, automatic watering systems are especially effective. In this way, several hours are required to apply 3 to 5 gallons per square foot. Damage to soil structure is minimal. Oxygen is not limited during leaching since the water carries some oxygen from the air as it slowly trickles into the soil.

Multiple leachings may be advisable if your soil has excellent structure, and will obviously not be damaged in intermittent heavy watering, and if your water is expensive.

Table 1 sets general soluble salt levels for soils based on a 2(water):1(soil) mixture. Levels for peat-lite mixes may be higher without adversely affecting plant growth.

Specific Crop Notes

Azaleas require an acid soil and respond to an acid fertilizer high in nitrogen such as 21-9-9 or 21-7-7. Continued use may drop the pH too far. Watch that the soil doesn't become overly acid. In general, add 3 lbs. limestone per cubic yard when growing in peat.

Bedding Plant soil should be prepared with proper amounts of limestone and superphosphate.

During January, February and March, the preferred fertilizer is 15-0-15 prepared from calcium and potassium nitrates. During warmer months, 20-5-30 or 20-20-20 may be used.

Carnations require a high potash-to-nitrogen ratio, especially during late summer and fall. The fertilizer should contain 1½ times as much potash as nitrogen. This will help overcome one of the causes of weak stems in midwinter. Using sodium nitrate during April through July will help alleviate browning of lower leaves on carnations to be carried over (see 11-0-17).

Chrysanthemums are heavy feeders and respond to high fertilizer rates. The potash levels should be a bit higher than the nitrogen (19-5-24 or 20-5-30).

Geraniums should thrive with any complete fertilizer. For details, consult our geranium bulletin.

Hydrangea – To tie up aluminum in the soil and assure pink flower color, fertilizers high in phosphates such as 12-41-15 or 17-35-16 are used.

For blue hydrangeas, avoid fertilizers containing phosphorus. Use one such as 15-0-15 or 13-0-22 prepared with ammonium sulfate to aid in maintaining a low pH.

Lilies – Calcium nitrate is a good lily fertilizer. To keep a balance in our low-potash soils, it is combined with potassium nitrate to give 15-0-15 (winter nitrate) or 15-0-22 (winter potash). Superphosphate should not be added to lily soils. Fertilizers should contain little or no phosphorus. For more details, consult the Easter lily bulletin.

Poinsettias may be fertilized with potassium nitrate, but it is better combined with calcium nitrate as in 15-0-22 (winter potash) to better suit the critical, but lower demand for potash. Alternating this with a complete fertilizer such as 20-5-30 may be desirable.

General Foods – If soil is properly amended with lime and superphosphate according to soil tests, little soluble phosphorus need be applied. General purpose formulas such as 17-6-27 (general) and 20-5-30 (editor's favorite) are most appropriate.

FUNCTIONS OF THE NUTRIENTS IN GREENHOUSE PLANT NUTRITION

NITROGEN

Role of Nitrogen in Plants.

Nitrogen is required in relatively large amounts by plants. It is a constituent of many plant compounds, including amino acids, nucleic acids and several enzymes. Nitrogen is also found in energy transfer materials such as chlorophyll, ADP (adenosine diphosphate) and ATP (adenosine triphosphate). A severe shortage of nitrogen will halt the processes of growth and reproduction in plants.

Nitrogen – Soil Forms and Their Measurement.

Both organic and inorganic forms of nitrogen are found in soils. Inorganic nitrogen exists in three different forms: ammonium (NH_4^+), nitrite (NO_2^-), and nitrate (NO_3^-). The NH_4^+ and NO_3^- forms predominate; only rarely is there more than a trace of NO_2^- present in soils.

More than 95% of the nitrogen in field soils is in organic form. Since plant roots are unable to absorb most organically combined forms of nitrogen, these forms must be broken down to NH_4^+ to be available to plants. Microorganisms called ammonifiers convert organic nitrogen to NH_4^+ in the soil. The NH_4^+ is then converted to NO_3^- by another group of organisms called nitrifiers. NH_4^+ and NO_3^- are the common forms of nitrogen absorbed by plant roots.

Nearly all plants absorb most of their nitrogen as NO_3^-. For this reason, measuring the amount of NO_3^- in some soils is helpful in evaluating their nitrogen status. Soil NO_3^- levels depend upon several factors, including amounts and types of nitrogen fertilizers added, frequency of application, losses due to leaching, soil aeration, and the rate of decomposition of organic soil nitrogen.

In outdoor soils, decomposition of organic matter accounts for a relatively large amount of the NO_3^- found in these soils. Routine soil tests do not measure the soil's potential to produce NO_3^-. Furthermore, soil samples from poorly aerated fields may develop higher NO_3^- levels under the warm, well-aerated conditions of the soil preparation room of the soil testing laboratory. For these reasons, NO_3^- tests on outdoor soil samples have little value.

A different situation exists for greenhouse soils. Here, by frequent applications of nitrogen fertilizers, NO_3^- levels are usually maintained at relatively high levels for optimum plant growth.

Nitrite nitrogen (NO_2^-) is toxic to plants in very small quantities. However, NO_2^- injury is relatively uncommon because of its rapid conversion to NO_3^- in most soils. But, as mentioned previously, NO_2^- may accumulate in alkaline soils, especially in those containing large amounts of NH_4^+. This accumulation occurs following the application of large quantities of urea or NH_4^+ salts to soils of high pH. An increase in pH as a result of urea hydrolysis, NH_4^+ additions, or careless use of hydrated lime will also increase both NH_4^+ and NO_2^- levels.

In intensively cultivated soils, NH_4^+ is frequently found to be phytotoxic. NH_4-N toxicity is alleviated when the nitrifying soil bacteria oxidize the NH_4^+ to NO_3-N. This NH_4-N oxidation may be inhibited by many factors such as low temperature, low soil pH, poor aeration, excessive metallic ions or salts and, possibly, by the use of certain fungicides.

As with NO_3^- problems, NH_4^+ problems can be diagnosed by soil tests. Because NO_2^- difficulties occur more frequently on soils of high pH and are induced by high NH_4^+ concentrations measurable by analysis, routine soil tests for NO_2^- are not run.

Organic nitrogen fertilizers

Several different kinds of organic nitrogen materials have been used in greenhouses. These include such natural organic fertilizers as dried blood, sewage sludge, fish emulsion, cottonseed and linseed meals, tobacco stems, meat meal, castor meal, and manure. Synthetic organic materials commonly used are urea and urea-formaldehyde.

The principal value of these organic compounds is that they release nitrogen slowly over a considerable period of time. The rate of release depends upon temperature and moisture. Soil tests do not measure the rate or extent of this slow release and therefore mean less in evaluating the soil nitrogen status.

Fertilizer schedules affect NO_3 levels to a far greater extent than does decomposition of soil organic matter. By accurately measuring the NO_3^- level in the soil, the soil test indicates quite reliably the nitrogen status of greenhouse soils. The soil test results can, therefore, reflect fertilizer schedules and other management practices.

As suggested above, nitrogen problems in greenhouse soils are diagnosed best by soil tests. Problems arise if there is either too little or too much nitrogen present as NO_3^- or if there is an excess of NO_2^- or NH_4^+.

Shortages of nitrogen are not always manifested in deficiency symptoms in the plant. When the nitrogen supply is inadequate, a general slowing or stunting of growth occurs. In field crops, this condition is called "hidden hunger"; it means that a desirable plant response can be effected by adding fertilizer even though deficiency symptoms are not present.

Soil tests usually indicate "hidden hunger" when soil nitrogen levels are low. Research in New York on a rose cultivar showed that raising soil NO_3^- levels (as measured by the Spurway test) from 2 to 50 ppm increased the average number of flowers per square foot from 6.3 to 13.8. Another conclusion reached in this study was that growers should maintain the same soil nitrogen levels at all seasons.

If nitrate shortages are not diagnosed in time by soil tests, plant deficiency symptoms will develop. The plant begins to show a chlorosis or yellowing of its leaves. This begins low on the plant and proceeds upward. By the time this yellowing appears, the plant has already been considerably stunted and its economic value has probably declined. Another symptom of low nitrogen is reddening (anthocyanin accumulation) of the lower leaves of some plants.

When soil nitrates are present in toxic amounts, the plant injury appears as it would with an excess of soluble salts. Yellowing of the upper parts of the plant, marginal leaf burn and wilting are symptoms. Excessively high nitrate levels can be analyzed readily by soil tests.

Special problems may arise with manure. With the frequent watering recommended for most greenhouse plants, the presence of large amounts of manure can allow soil microorganisms to multiply rapidly and deplete the soil oxygen supply. Ammonium nitrogen may accumulate (especially if hydrated lime is used) and roots may be damaged, resulting in decreased water and nutrient uptake by the plants. The difficulty in obtaining manure and the problems encountered have led to decreased use of this material.

Synthetic organic nitrogen fertilizers usually release nitrogen more quickly than natural organic materials. The synthetic compounds, like the natural materials, are not fully measured by soil tests. Under certain conditions, especially high soil temperatures, considerable amounts of nitrogen can be released by the synthetic organic compounds, and injury can result.

Although their use has generally decreased, organic sources of nitrogen are valuable in greenhouse soils. The current trend, however, is to use them in relatively small amounts in conjunction with inorganic nitrogen fertilizers to assist in maintaining an active microflora in greenhouse soils.

Inorganic Nitrogen Fertilizers

The most common nitrogen sources include ammonium sulfate, ammonium nitrate, calcium nitrate, sodium nitrate, and potassium nitrate. These inorganic nitrogen fertilizers are completely soluble in water and become available to the plant as soon as they are applied to the soil. An advantage in their use is that the amount of nitrogen available to the plant can be measured by soil tests. Periodic testing of the soil will indicate whether or not your fertilizer program is appropriate for the crop.

Fertilizer Applications

Nitrogen and other fertilizers can be applied to greenhouse soils in a variety of ways. The reader is referred to Tables 2 and 5 of this bulletin for more information on this subject.

Nitrate vs. Ammonium Nitrogen in Pansy Fertilization

Pansies are frequently damaged by high levels of ammonium nitrogen. This isn't surprising. They are more sensitive to excesses than many other flowers. High soluble salt, nitrate or potassium levels can cause poor growth.

The symptoms of ammonium toxicity are stunting and chlorosis with poor root development. Theoretically, it might be argued that this is quite likely a minor nutrient deficiency induced by ammonium toxicity. Practically speaking, the avoidance of high levels of ammonium nitrogen alleviates the problem.

To avoid ammonium toxicity, nitrate fertilizers should be used. A combination of 2 parts calcium nitrate and 1 part potassium nitrate by weight will give a 15-0-15 soluble fertilizer. Use this or 15-0-22 (Table 5).

Ammonium nitrogen toxicity isn't the only problem encountered in the production of pansies, but it is very frequent. Using nitrate fertilizers may solve this problem.

PHOSPHORUS

Phosphorus has been called the "key to life" because of its role in most life processes. In plants, phosphorus has many functions including: (1) cell division, (2) flowering and fruiting, (3) crop maturation, (4) root development, and (5) starch formation.

When plants are unable to obtain enough phosphorus, one or more of these functions slows down or ceases altogether. Phosphorus deficiency symptoms then develop. For example, decreased cell division results in stunting of plants. When sugar in the plant is not converted to starch due to a lack of phosphorus, anthocyanins are formed. These appear as purple spots or streaks in leaves and stems. Another deficiency symptom is abnormally dark-green coloration in plants.

In soils, phosphorus exists in both organic and inorganic forms. Mineral soils, especially acid ones, are notorious for their ability to fix or tie up phosphorus in forms not readily available to plants. The chief culprits in this fixation are calcium, iron, and aluminum ions, hydrous oxides of iron and aluminum, and silicate clays. There is little if any clay in most greenhouse growth media. Therefore phosphorus fixation is not the problem that it is in most field soils. Clay not only can furnish large amounts of aluminum and iron but is also capable of fixing added phosphorus. Fixation by calcium may be a problem, but only if soil pH values exceed 7.0.

In general, the greater the amount of mineral soil in a greenhouse soil mix, the greater will be the fixation of added phosphorus. Therefore, soil mixes containing a mineral soil will contain less soluble phosphorus than artificial mixes such as peat-lites which have been similarly fertilized.

One advantage of phosphorus fixation by soils is that little if any phosphorus is lost by leaching. In general, leaching is not a problem in most greenhouse soil mixes.

The most commonly used phosphorus fertilizer is 20 percent superphosphate (0-20-0-). This material is preferred over triple superphosphate (0-40-0 or 0-46-0) because it supplies sulfur as well as calcium and phosphorus. Ammonium and potassium phosphates can also be used. Various slow release fertilizers should be used at rates recommended by the manufacturer.

In general, 5 pounds of 0-20-0 per cubic yard of soil mix will provide an adequate level of phosphorus for the entire growing season. If 0-40-0 is used at 2½ pounds per cubic yard, incorporate an equal amount of gypsum.

Although superphosphate can be added to soil mixes at relatively high rates without developing excess soluble salts, very high soil phosphorus levels should be avoided. The reason is that certain micronutrient deficiencies, particularly zinc and copper, may be induced.

If a phosphorus problem (or a micronutrient problem) in a soil mix is suspected, have the mix tested. The procedure used at The University of Connecticut soil testing laboratory measures only the most readily available phosphorus. The results show accurately whether a deficiency or excessively high level of phosphorus exists in the soil.

POTASSIUM

Potassium (K) or potash (K_2O) as it is known to many growers is an element needed in relatively large amounts by plants. It is one of the three macronutrients that is commonly in short supply in the soil and limits crop yield.

Potassium has many functions in plants. There is considerable evidence that it plays important roles in photosynthesis and respiration, thus affecting the efficiency of light utilization in the greenhouse. Carbohydrate metabolism and translocation are both affected by potassium, as are the organic acid and nonprotein nitrogen content of plant tissue. Potassium also affects the disease resistance and quality of many crops.

In soils, potassium exists in nonexchangeable, exchangeable, and soil-solution forms. The last two are considered readily available to plants. That is, plants pick up exchangeable and soil-solution potassium with relative ease. As the level of exchangeable potassium is lowered by plants, nonexchangeable potassium partially replaces it. In this way, nonexchangeable potassium is important under conditions of sustained plant growth over several growing seasons when potassium fertilizer is not applied.

Greenhouse soils and their management differ from most outdoor soils and their management with respect to the potassium nutrition of plants. First, the fertilization schedule employed by greenhouses assures, in most cases, an adequate and fairly uniform level of soil-solution potassium. Thus, plants grown in most greenhouses are not at all dependent upon sources of nonexchangeable potassium for their supply of the nutrient. Under constant-feed greenhouse conditions, where potassium and other nutrients are added in small amounts at every watering, even exchangeable potassium loses the significance it has under outdoor conditions.

Studies have shown that potassium is held relatively loosely in the soil by the negatively charged sites on organic matter. This means that potassium is likely to be leached from greenhouse soil mixes more rapidly than calcium or magnesium. For this reason, the potassium status of greenhouse soils should be checked by periodic soil testing.

The most important factor affecting potassium availability to plants grown under greenhouse conditions is the concentration of other soil nutrients. In particular, high soil levels of magnesium and/or calcium decrease the plant's ability to obtain potassium.

It is also important to maintain a proper balance of soil nutrients to insure adequate potassium nutrition of plants. The potassium level in the soil (or in the fertilizer schedule) may be adequate for crops growing under conditions of low nitrogen and phosphorus, but may become inadequate if these are increased. Most greenhouse soils in the Northeast require 50% more potash than nitrogen in the fertilizer.

When nutrient imbalance is caused by too much nitrogen and too little potassium, plant leaves are large but relatively inefficient at photosynthesis. This results in an abnormal concentration of nitrogen compounds compared to carbohydrate in the leaf. This condition leads to greater liability of these leaves to fungal and bacterial diseases and to decreased drought resistance compared with those plants receiving more adequate potassium fertilization.

Potassium deficiency symptoms first appear on the older leaves of the plant as an interveinal chlorosis near the leaf margins. In some plants, the first sign of potassium deficiency is a white speckling or freckling of the leaf blades. The chlorosis develops from light yellow to tan, becoming brown, and finally drying to a "scorch". High soluble salt levels may increase the severity of potash deficiency symptoms. These symptoms are sometimes also evident in young leaves, as indicated in Table 6.

Determination of potassium levels in soil is one of the most accurate in the soil testing program. It reliably indicates the presence of too little or too much potassium. In addition, tests for calcium, magnesium and nitrogen indicate when an imbalance between potassium and one or more of these nutrients exists or is likely to develop.

A number of potassium fertilizers can be used to maintain crops and correct potassium deficiency. The reader is referred to tables 2 and 5 of this bulletin for fertilizer recommendations.

MAGNESIUM AND CALCIUM

Magnesium (Mg) and calcium (Ca) are two of the six macronutrients. Magnesium is necessary for chlorophyll formation and is the core of the chlorophyll molecule. Magnesium also plays a role in the phosphate metabolism of plants and is a specific activator for a number of enzymes.

In the soil, magnesium from exchangeable forms moves into the soil solution as the element is taken up by plant roots. In this way, magnesium in the soil solution is maintained at an adequate level for plant growth until the exchangeable sources begin to wane. When magnesium in both water soluble and exchangeable forms becomes low, a deficiency may develop in plants.

A low level of available magnesium in the soil is not the only condition which will adversely affect the magnesium nutrition of plants. Nutrient imbalances caused by large additions of potassium, ammonium nitrogen, or calcium can bring on or aggravate magnesium deficiency. Such a deficiency can arise even when the soil magnesium level, as measured by a soil test, appears to be adequate.

For example, magnesium deficiency in chrysanthemums caused by high applications of potassium has been reported. Chlorosis which had affected most of the foliage reduced the marketability of the crop. Applying magnesium to the soil even at high rates did not correct the problem. Cessation of potassium fertilization, however, gave control.

Another condition which leads to magnesium deficiency in plants is an imbalance between magnesium and calcium. Gypsum (calcium sulfate) is often added to the soil in order to supply calcium without raising the soil pH. Magnesium is seldom added with the gypsum. This practice does not replenish the magnesium level and results in a high calcium-magnesium ratio which may induce magnesium deficiency. The opposite may occur when high rates of magnesium are applied (for example, magnesium ammonium phosphate at over 5 lbs./cu. yd.) resulting in calcium deficiency.

In the early stages of magnesium deficiency in plants, symptoms appear first midway up the stem on newly mature leaves, usually in the later stages of plant development. There is a loss of green color between the leaf veins, followed by increasing chlorosis. This may start at the leaf margin or tip and progress inward between the veins. In more acute stages, the entire leaf may turn yellow or other bright colors. The leaves curl in some plants, and premature defoliation may occur.

In greenhouse soils, magnesium deficiency seldom develops when dolomitic limestone is used to correct soil acidity. Dolomitic limestone contains appreciable quantities of magnesium carbonate along with the calcium carbonate. However, when dolomitic limestone is not used or when unusually large amounts of potassium or calcium are applied, the chance for magnesium deficiency increases significantly. By knowing the soil's pH and its potassium, calcium, and magnesium levels through soil testing, it is possible to avoid magnesium deficiency or to correct it if it has already appeared.

Magnesium deficiency may be corrected by either soil applications or foliar sprays. Dolomitic limestone should be added when a rise in pH is desirable. Otherwise, Epsom salts (magnesium sulfate) should be applied to the soil. See Table 2 of this bulletin for appropriate rates. Epsom salts also provide sulfur (S), another macronutrient, one seldom found in insufficient levels in greenhouse soils.

If foliar sprays are used, it should be remembered that they provide only a temporary recovery. The soil condition leading to the deficiency should be corrected. Solutions of Epsom salts, magnesium nitrate or magnesium chloride can be used as foliar sprays. There is some evidence that the nitrate and chloride salts are more effective in correcting deficiency than Epsom salts.

MICRONUTRIENTS

Analyses of Growth Media

Samples of greenhouse soils are seldom tested for micronutrients for the following reasons:

1. Micronutrient availability to plants is affected more by soil pH than by any other single factor. Excessive (toxic) levels of iron, manganese, zinc, and copper seldom occur above pH 6.0. Deficiencies are unlikely to develop below pH 7.0. Molybdenum availability is just the opposite; as the pH increases, molybdenum levels also increase. Thus, deficiencies or excesses of most of the micronutrients can be corrected by adjusting soil pH.
2. Interpretation of the results may be difficult or nearly impossible. There is still little definitive information on what constitutes deficiency or excessive levels of micronutrients in greenhouse soil mixes. Hopefully, this situation will improve as soil analysis is supplemented more fully by plant tissue analysis for micronutrients.
3. Many of the analyses involved are complicated and time consuming. Special precautions must be exercised to avoid contamination. Due to analytical complexities, the possibility of contamination and the very small quantities of some of the micronutrients, results for these nutrients are less likely to be accurate than those for nutrients tested routinely.

Specific Micronutrient Problems

Chelated Iron Rates. Some label recommendations for foliar application of iron chelates are higher than necessary for certain greenhouse crops. A common recommendation is 1 lb per 100 gallons. This rate will frequently burn foliage on plants such as hydrangeas. A more appropriate rate is 3 or 4 oz. per 100 gallons.

Iron chlorosis is very seldom, if ever, due to a lack of iron in the soil. It may be caused by many factors including incorrect pH, low temperature, lack of aeration (too much water), nematodes, symphilids, nutrient imbalance, salt toxicity or anything that interferes with normal root health.

Applying iron to correct a deficiency is generally a stop-gap measure. It will help the plant stay healthy while the condition which caused the deficiency can be corrected.

While there are several types of chelated iron available, any of them should give good results if used at 4 oz. per 100 gallons and applied as a drenching spray over the foliage along with one pint per square foot on the soil or as a normal watering for pot plants.

Manganese, one of the elements needed by plants in trace amounts, is seldom mentioned in connection with greenhouse fertility problems. Indeed, deficiency of this nutrient is almost unknown in floriculture crops in New England.

The development of either manganese deficiency or toxicity in plants can be easily prevented. Soil pH is the factor which most affects the availability of manganese. As the pH increases, manganese becomes increasingly unavailable. Deficiency levels for plant growth occur most often above the soil pH of 7.0 and almost never below pH 6.0. As the pH decreases, manganese availability increases. Toxic levels are more likely to occur at pH 5.0 and below.

Symptoms of manganese deficiency are stunted plant growth and yellowing of new or top leaves. The leaves turn light green to yellow with all veins remaining distinctly green. Spots of dead tissue may appear on the leaves. Manganese deficiency can be distinguished from iron deficiency by the nature of the chlorosis. With iron deficiency, new leaves turn almost white with the principal veins remaining green.

Symptoms of manganese toxicity in mature plants include chlorosis and crinkling of the leaves, with marginal cupping. After the seedling stage, necrosis (death) of small, irregular patches, usually dark brown, is the first sign of manganese toxicity. These are scattered over the entire leaf surface between the principle veins.

Steam treatment of soil can increase manganese availability, in some cases to toxic levels. Some sphagnum peats contain excessive amounts of manganese which may be liberated during steam pasteurization.

One cause of manganese toxicity can be the addition of too much in an attempt to correct manganese deficiency. Caution should be exercised in the use of all micronutrients.

To correct known manganese deficiency, add manganese sulfate at a rate of one-half ounce per 100 square feet. In some cases, lowering soil pH by the addition of sulfur or aluminum sulfate will provide sufficient manganese to plants. Similarly, manganese toxicity may be corrected through the addition of agricultural limestone.

Greenhouse crop nutrition is a dynamic science. To help keep the growers of Connecticut abreast of changing technology, the Connecticut Greenhouse Crop Production Task Force has prepared this expanded bulletin, the fourth on this subject since 1962. We hope this will be a valuable reference for you.

The Connecticut Cooperative Extension Service educational programs at all levels, neighborhood, community, town, county, area and state are provided on a nondiscriminatory basis and as such are open to all without regard to race, color, age, national origin, sex or religion. Issued in furtherance of the Acts of Congress of May 8 and June 30, 1914, by The University of Connecticut Cooperative Extension Service, E. J. Kersting, Director, Storrs, Ct. 06268.

(JULY 1976, UP, 3M)