Artificial media in horticulture— their formulation and fertilization

Agriculture Canada

Publication 1726 /E

Canada

Artificial media in horticulture— their formulation and fertilization

for — bedding plants
— vegetable seedling blocks
— greenhouse vegetables
— container-grown shrubs
— home gardening

E. F. Maas
Research Station, Agassiz, B.C.

and

R. M. Adamson (Retired)
Saanichton Research and Plant Quarantine Station, Sidney, B.C.

Agriculture Canada Publication 1726/E
available from
Communications Branch, Agriculture Canada,
Ottawa K1A 0C7

Cat. No. A53-1726/1982E ISBN: 0-662-11774-3
Printed 1982 Reprinted 1989 2M-11:89

Également disponible en français sous le titre
Les milieux de culture artificiels en horticulture— préparation et fertilisation.

CONTENTS

Preface

The last decade has seen an almost complete change in the nursery and greenhouse industries from the use of mineral soil to a wide range of substitutes. This has been brought about by the shrinking supply of good-quality loam, an unprecedented increase in pot-plant production, and a change from soil beds to containers for greenhouse vegetables. Peat–vermiculite and sand–peat mixtures have proven to be reliable substitutes and have been widely adopted. In British Columbia, sawdust, ground bark, and peat–sawdust mixtures are now the mainstay of the nursery and greenhouse industries because of their low cost, light weight, and ease of drainage, and because of the uniformity of plants produced. These materials, however, require new management methods with especially close attention to proper formulation of the mixtures and the complete and frequent supply of the plants' nutrient requirements.

Dr. J. E. MILTIMORE
Director
Research Station, Agassiz, B.C.
September 1980

Introduction

Emphasis on potting media in Canada has changed gradually from the almost exclusive use of soil mixtures to the development of completely artificial substrates for producing an increasing proportion of container-grown plants. Nurserymen found from experience that productive field soils confined to containers often gave inferior results because of compaction and inadequate drainage, but that improvements could be made by incorporating materials such as peat, sand, leaf mould, and rotted manure. During the 1930s the John Innes Horticultural Institute showed that standardized soil mixtures could be used for a wide range of plants. This led to acceptance of the John Innes seed and potting composts (1) in England and no doubt stimulated development of the U.C. (University of California) (2) sand–peat mixes and the Cornell (3) peat–vermiculite mixes.

Soil-based mixes

The John Innes seed compost is made by volume, from two parts steam-pasteurized loam, one part peat, and one part medium-coarse sand with the addition of 1.2 kg of superphosphate (0-18-0) and 0.6 kg of ground limestone per cubic metre of mixture. This is suitable for seed sowing and the rooting of cuttings. The John Innes potting compost

(JIP-1) for general planting is made by volume, from seven parts steam-pasteurized loam, three parts peat, and two parts medium-coarse sand to which the following fertilizers are added:

	Per cubic metre
Hoof and horn meal (or soybean meal)	1.2 kg
Superphosphate (0-18-0)*	1.2 kg
Potassium sulfate (0-0-50)	0.6 kg
Ground limestone	0.6 kg

*Note: Formulas calling for superphosphate (0-18-0) may use a mixture of 40% triple superphosphate (0-45-0) and 60% calcium sulfate by weight if 0-18-0 is not obtainable.

Where higher nutritional levels are required the amounts of fertilizers and limestone to be added can be doubled (JIP-2), or trebled (JIP-3).

These standardized mixtures were widely adopted in Britain, but to a lesser extent in Canada where varying soil mixtures were developed to suit individual requirements. The increasing labor cost for pasteurizing and preparing soil-based mixtures and the difficulty in obtaining soils of suitable quality have made nurserymen receptive to the use of artificial media which are easily prepared, are reliable, and do not require pasteurization if properly handled.

Artificial mixes

The development of nutrient-solution culture of greenhouse tomatoes in sawdust (4) at Agriculture Canada's Saanichton Research and Plant Quarantine Station, Sidney, B.C. in the mid-1960s, awakened the nursery and bedding-plant industry in British Columbia to the feasibility of growing plants in artificial media. At the same time that container production of ornamentals using the U.C. system of sand–peat mixes and wood by-products was developing on the U.S. west coast, growers in the eastern USA and Canada were propagating bedding plants in a mixture of peat and vermiculite developed at Cornell University, Ithaca, N.Y.

Artificial media are being tailored to meet the needs of plants and with suitable nutrient formulas can provide all the requirements for precision growing. The purpose of this publication is to list the ingredients used in preparing potting mixtures and to provide suitable nutrient formulas. Since contamination of sawdust or bark mixtures by soil will initiate decomposition and create nitrogen deficiency problems, plants to be grown in these mixtures should be started only in artificial media.

Peat, sawdust, and ground bark have been the favored ingredients of potting mixtures in British Columbia because of their low cost, light weight, and ease of handling. Sawdusts from Douglas fir (*Pseudotsuga* *menziesii* (Mirb.) Franco) and western hemlock (*Tsuga heterophylla* (Raf.) Sarg.) are acceptable, as well as fir bark, but other kinds have also been used successfully. The toxicity of hemlock bark and fresh sawdust from western red cedar (*Thuja plicata* Donn) has been noted on sensitive plants such as tomatoes, but our recent tests show that sawdust from immature cedar is usually satisfactory. The safety of each batch of cedar sawdust can be tested within a week by planting a few bean seeds into representative samples. Since cedar sawdust is cheap and readily available the feasibility of using it should be considered.

Sawdusts from deciduous trees are less suitable because they decompose more rapidly than coniferous sawdusts. Composted materials are not recommended as they are costly to prepare and tend to be variable in their nutrient and physical properties. Other materials such as sand, gravel, pumice, perlite, vermiculite, diatomite, and heat-treated shale have also been successfully included in a variety of mixtures. The peat referred to in these formulations is the ground sphagnum peat available commercially. It has been widely adopted because of its uniformity and high moisture-holding capacity, and because it does not need sterilization. These qualities are not equaled in marsh peats (i.e., sedge peats) and the more decomposed black peats (peat humus).

Root production after one season's growth of *Thuja occidentalis* 'Pyramidalis' in a sawdust–peat-based growth medium, *left*, and in soil, *right*.

Nutrients may be supplied to the plants by incorporation of slow-release fertilizers, by nutrient-solution feeding on a day-to-day basis, or by premixing some of the fertilizer with the medium and feeding the remainder in solution. All these methods require surface application of water or nutrient solution, with a small excess being allowed to leach through to prevent the buildup of soluble salts. Care must always be taken to ensure that the water content of an artificial medium is frequently replenished to prevent dissolved fertilizers from becoming too concentrated and damaging the plants.

Sowing media

The Cornell peat-lite mixes (see Media for bedding plants) are suitable for both seed germination and bedding plants. The Saanichton sowing mix, although excellent for seed germination, is not suitable for bedding plants because it gradually loses its good drainage and aeration properties due to settling. These mixes do not require pasteurization, but care must be taken to prevent contamination with pathogens throughout all stages of handling from initial mixing to final filling of flats or containers.

The Saanichton sowing mix consists of equal volumes of medium sand, ground sphagnum peat, and granular perlite. Mix these ingredients and wet them with half-strength nutrient solution from Formula 1 (see Appendix), using the 126 parts per million (ppm) nitrogen level. All media containing absorbent materials such as peat or sawdust should be prepared a day before use, to ensure that moisture levels are adequate. Rewet immediately before but not after seeding. To prevent damping off, dust the seed with a recommended fungicide. When the seedlings need moisture, apply the half-strength nutrient solution with added fungicide.

Transplanting media

Media for bedding plants

The Cornell peat-lite mixes are commercially available and are suitable for seedlings, bedding plants, pot plants, and greenhouse vegetable production. They are prepared from 1:1 peat–vermiculite, 1:1 peat–perlite, or 2:1:1 peat–vermiculite–perlite mixtures by volume measurement. For seedlings and bedding plants, add the following to a 1:1 peat–vermiculite mixture:

	Per cubic metre
Ground limestone	3 kg
Superphosphate (0-18-0)*	1 kg
Calcium or potassium nitrate	600 g
Wetting agent (e.g., Aqua grow or Triton B)	100 mL
Fritted trace elements (F.T.E.)	75 g

*Note: Formulas calling for superphosphate (0-18-0) may use a mixture of 40% triple superphosphate (0-45-0) and 60% calcium sulfate by weight if 0-18-0 is not obtainable.

For bedding plants and pot plants, feed with nutrient solution (1.2 g potassium nitrate dissolved in 1 L water, or use other nitrogen fertilizer (3)) after 2–3 weeks of growth. An alternative is to supplement this premix formula with 3 kg of Osmocote (14-14-14) and 3 kg of Mag-Amp (7-40-6) for each cubic metre of medium (3). When slow-release fertilizers such as these are used in any artificial medium an occasional overwatering is required to remove any accumulation of excess soluble salts.

The Saanichton potting mix is a modification of the Cornell mix. It has the addition of 1.8 kg of hydrated lime per cubic metre of mix and a 2:1 peat–vermiculite volume measure, to take advantage of the lower cost of sphagnum peat. Minor elements are included in the nutrient solution to ensure uniform availability because this is not always achieved with F.T.E. Soak the medium with half-strength N-126 ppm nutrient solution from Formula 1 (see Appendix) before planting, followed by periodic application of N-168 at full strength to supply both the nutrient and water requirements of the plants. Where only a small quantity of nutrient solution is required a good substitute for Formula 1 can be found in a commercial hydroponic fertilizer 14-7-21. Dissolve 12 g of this fertilizer in 10 L of hot water followed by 3 g of magnesium sulfate (Epsom salts) according to instructions on the package. This will make a solution containing 168 ppm of nitrogen (N), 84 ppm of phosphate (P_2O_5), 252 ppm of potash (K_2O), 93 ppm of calcium (Ca), 30 ppm of magnesium (Mg), and all the required minor elements. This formulation can be used for home hydroponic units and it is especially well suited for watering house plants growing in artificial media. The ingredients for this formulation are shown in Formula 3 (see Appendix). If it is more convenient, the magnesium requirements and some additional calcium can be supplied by incorporating 2.4 kg of dolomitic lime (65 AG) into each cubic metre of potting medium.

The following formula developed at the Saanichton Research and Plant Quarantine Station provides the needed fertilizers in a slow-release form; therefore the plants require only watering until the transplanting stage is reached. Incorporate the following into a 2:1 peat–vermiculite mixture just before using:

	Per cubic metre
Osmocote (19-6-12)	3.0 kg
Osmocote (14-14-14)	1.5 kg
Mag-Amp (7-40-6)	6.0 kg
Hydrated lime	1.8 kg
Minor-element solution (see Appendix, Formula 1)	440 mL

Newly potted junipers in a soilless growth medium being loaded on a flat deck trailer for transporting to the nursery.

If plant growth becomes too lush it should be controlled by reducing the availability of water rather than lowering the greenhouse temperature. Omit the 19-6-12 and possibly the 14-14-14 for short-term bedding plants to reduce fertilizer costs, except when sawdust is present in the medium.

All these media have produced excellent transplants for commercial greenhouses and for the retail market. Local growers often prepare their own mixtures to reduce costs and to ensure the desired quality control which has occasionally been lacking in some of the commercial media. When vermiculite is in short supply, fir and hemlock sawdust or ground fir bark can be successfully substituted in the mixture. This is not normally recommended, however, because the moisture-retention capacity is reduced and more frequent watering is required.

Media for vegetable seedling blocks

Peat, peat–vermiculite, or peat–perlite mixtures are suitable for the production of vegetable seedling blocks, but the cost is too high for transplants on a field scale. A cheaper mixture using half and half sphagnum peat and black peat (peat humus from marshes) is widely used for seedling blocks in Europe and central Canada, but black peat is not readily obtainable in British Columbia. The alternative of mixing low-cost ground bark or sawdust with sphagnum peat is being investigated at Agriculture Canada's Agassiz Research Station, and promising results are being obtained.

For seedling blocks, incorporate a 5% volume of bentonite clay for a binder in 2:1 peat–vermiculite or peat–perlite mixtures or in peat alone and add one of the following fertilizer formulas.

	Per cubic metre	
	Formula A	Formula B
Osmocote 14-14-14 (omit for onions in Formula A)	1.5 kg	4.0 kg
Mag-Amp 7-40-6	6.0 kg	nil
Hydrated lime	1.8 kg	1.8 kg
Dolomitic lime (65 AG)	nil	1.8 kg
Minor-element solution (see Appendix, Formula 1)	440 mL	440 mL
Wetting agent	110 mL	110 mL

Media for flower cuttings

Artificial media are well suited to the rooting and growing of flower cuttings because rapid rooting is encouraged by their good aeration, and black stem rot is reduced. A 1:3 peat–sawdust mixture is suitable for rooting geranium cuttings and a 1:2 peat–sawdust mixture for poinsettias and chrysanthemums. Ground fir bark may be used in a half-and-half mixture with sawdust for geranium cuttings but bark alone remains too wet. A mixture containing equal parts of peat, sand, perlite, and sawdust is also a good rooting medium. The nutrient requirements of peat- or sawdust-based mixtures are met by the following ingredients, while extra nitrogen may be required for bark due to its more rapid initial decomposition (5):

	Per cubic metre
Osmocote (14-14-14)	2.4 kg
Superphosphate (0-18-0)	1.8 kg
Dolomitic lime (65 AG)	3.6 kg
Minor-element solution (see Appendix, Formula 1)	440 mL

Growing media

Fir and hemlock sawdusts have been the most important bases for soilless media in the British Columbia coastal nursery and greenhouse industries. Other materials used alone or in mixtures with sawdust include ground bark, sand, sphagnum peat, pumice, and fired clay, shale, or diatomite. Fresh hemlock bark and sawdust from mature western red cedar are often toxic to flowers and vegetables but are tolerated by hardier shrubs. The U.C. mixes (see p. 13) based on sand, peat, and forest wastes have had a strong influence on the development of the container-grown plant industry in British Columbia.

Media for greenhouse vegetables

Fir and hemlock sawdusts have been accepted almost exclusively as the artificial growing media for greenhouse vegetables in British Columbia, usually with a 1.3-cm sand topping to facilitate moisture distribution. Ground fir bark, sand–sawdust mixtures, and peat-based mixtures have proved to be equally productive, but have not equaled sawdust alone in ease of handling and in economy. These media are placed in plastic bags, plastic tubes (bolsters), pots, or wooden-sided beds isolated from the soil by plastic sheeting. A complete nutrient-solution feeding of greenhouse tomatoes based on Formula 1 (4) (see Appendix) provides for applications at one of three nitrogen levels, depending on stage of growth, while cucumbers (6) are grown at a single nitrogen level of 168 ppm.

Greenhouse tomatoes are also grown in premix formulas (4) in which the following base fertilizers are incorporated into fir or hemlock sawdust before transplanting:

	Per cubic metre
Superphosphate (0-18-0)	2.4 kg
Dolomitic lime	4.0 kg

Nitrogen, potassium, and minor element requirements are supplied as a dilute nutrient solution throughout the season (see Appendix, Formula 2) to meet the remaining needs of the crop. For tomatoes, the N-126 ppm level is used to 1st fruit cluster set, the N-168 ppm level is used to 3rd cluster set, and the N-210 ppm level is used after that. The N-168 ppm level is well suited to all stages of most other plants.

Slow-release fertilizers may be used as a premix for growing greenhouse tomatoes in peat-lite (1:1 peat–vermiculite) mixtures (3), but due to high costs this method has not been widely adopted commercially. The following formula will support tomato plants for a 6-month growing period without additional fertilizer requirements:

	Per cubic metre
Ground limestone	6.0 kg
Superphosphate (0-18-0)	1.5 kg
Potassium nitrate (14-0-44)	0.9 kg
Osmocote (14-14-14)	3.0 kg
Osmocote (19-6-12)	3.0 kg
Mag-Amp (7-40-6)	3.0 kg
Fritted trace elements	75 g
Wetting agent	110 mL

A premix of slow-release fertilizers in sawdust has not been as reliable as day-to-day nutrient-solution feeding for greenhouse tomatoes. Daily watering is still required, so little labor is saved by using slow-release fertilizers in greenhouse vegetable production.

In Manitoba (7) and in Europe (8) fertilizers and ground limestone are thoroughly mixed with coarse peat and placed in beds for greenhouse vegetable production. The beds are 60 cm wide and 23 cm deep with the bottom 3.8 cm lined with polyethylene film to create a moisture reservoir. A fertilizer formula developed by Dr. J. D. Campbell (7) at the University of Manitoba is available commercially. It consists of the following ingredients for a 0.17-m^3 bale or for 0.25-m^3 of loose sphagnum peat:

	Grams
Major and secondary nutrients	
Ground limestone	1503
Dolomitic limestone (65 AG)	1618
Triple superphosphate (0-45-0)	173
Potassium sulfate (0-0-50)	347
Calcium nitrate (15-0-0)	173
Ammonium nitrate (33.5-0-0)	231
Total	4045
Micronutrients	
Borate 46 (14.3% B)	2
Copper sulfate (25% Cu)	5
Iron sulfate (20% Fe)	11
Iron chelate (Fe 330 10% Fe)	4
Manganese sulfate (25% Mn)	4
Zinc sulfate (23% Zn)	4
Sodium molybdate (40% Mo)	1
Total	31
Total weight	4076

Additional nitrogen and potassium will be required weekly for long-season crops. This formula may also be used in a 1:1 fine peat—vermiculite mixture at 4 kg/m^3 (4 g/L) for starting seedlings. This is at one quarter the level used here for growing plants.

Media for potted nursery plants

The U.C. mixes (2) for container-grown plants are based on fine sand and sphagnum peat ranging from 100% sand to 100% peat with 3:1, 1:1, and 1:3 mixtures being the most useful. Sawdust, wood shavings, or rice hulls may be substituted for all or part of the peat, provided they satisfy the physical and chemical requirements of the original mixture. Fertilizers are incorporated into the growing mixture according to several different formulas, depending upon crop and growing method. Supplementary fertilizers may be added during growth of the plants, either dry or in solution. Artificial mixtures based on fine sand and peat have tended to become waterlogged in the high-rainfall climate of coastal British Columbia and require modification with coarser sand, sawdust, or ground bark.

Peat–sawdust mixtures and ground bark alone are well suited to container-growing of nursery stock because they are inexpensive, well drained, and light in weight and have a fairly good moisture-holding capacity (which can be increased by the addition of more peat). The addition of 10% sand to a peat–sawdust mixture is not recommended because it reduces aeration and drainage by filling the larger pores. However, the addition of 40% medium sand to sawdust alone is beneficial, since it reduces excessive porosity of the sawdust and increases its moisture-holding ability, but it will increase the weight of the medium and affect the ease of handling. Fir and hemlock sawdusts are most widely used in peat–sawdust mixtures, but spruce and pine sawdusts should also be suitable. Although fresh cedar sawdust may be toxic to vegetative plants, sawdust from dry heartwood cedar has not significantly damaged coniferous shrubs. For growing containered shrubs (9) over an extended period in ground bark or in a 1:2 or 1:3 peat–sawdust medium, incorporate the following ingredients and top-dress spring-planted shrubs in August with 12 g of Osmocote (14-14-14) per pot:

	Per cubic metre
Osmocote (19-6-12) (use 50% less for bare-rooted cuttings)	4.8 kg
Superphosphate (0-18-0)	2.4 kg
Calcium sulfate (Gypsum)	1.2 kg
Dolomitic lime (65 AG)	3.0 kg
Minor-element solution (see Appendix, Formula 1)	1.0 L

Many other slow-release fertilizers such as Ortho timed-release 12-6-6 and Agriform 14-4-6 container tablets should produce as satisfactory results as does Osmocote. If obtainable, use non-chelated minor-element solutions for extended season retention rather than the more highly soluble chelated minor elements. If the chelated form is used in the mix, apply it again twice during the growing season at 22 mL of minor-element stock solution per 100 L of water as a liquid feed.

For indoor and summer shrubs to be supplied with nutrient solution on a regular basis, incorporate 3 kg of dolomitic lime (65 AG) per cubic metre of ground bark or peat–sawdust mixture. For the first 10 weeks, feed with a nutrient solution containing 0.6 kg of 20-20-20 per 1000 L, thereafter including an additional 0.3 kg of 34-0-0 per 1000 L. Add 22 mL of minor-element stock solution (see Appendix, Formula 1) to each 100 L of nutrient solution once a month.

Various container-grown ornamental plants being grown commercially in sawdust–peat mixtures.

Artificial media for home gardens

The use of artificial media need not be confined to commercial greenhouses; they can also be used for raised outdoor garden beds to avoid weeds or problem soils. If facilities are available for daily watering or nutrient-solution feeding, any of the methods described in the section on Media for greenhouse vegetables are suitable, using sawdust as the growing medium. At the end of the crop season the decomposed sawdust can be salvaged to make a good compost for improving the soil structure in the rest of the garden.

Ground fir bark or mixtures of sand and sawdust (3:1) or peat and sawdust (1:2) are also good growing media and would not require as frequent watering as would sawdust alone. Uniform water distribution can be enhanced by covering the medium with 1.3 cm of medium-coarse sand and using a drip or soaker application system.

In the Mittleider method (10) 20 cm-deep wooden-sided beds are filled with a "custom-made soil" for growing vegetables outdoors or in inexpensive polyethylene greenhouses. The medium consists of a mixture of any of the following ingredients: sand, sphagnum peat, sawdust, perlite, or styrofoam. Suitable local substitutes may also be available. Lime, boron, nitrogen, phosphorus, potassium, and magnesium fertilizers are incorporated into the medium before planting and supplied at intervals during the growing season as a topdressing. Water is supplied from either rain or hose watering. Details of bed construction, growing media, fertilizer formulations, and garden management are in *More food* *from your garden* (10). Plastic sheeting may be used at the bottom of the bed to separate the growing media from disease- or nematode-infested soil. If these problems are not present, plastic sheeting is not necessary and the plants can be allowed to root into the soil to provide a larger moisture reservoir and an additional source of nutrients. This method works well for beds placed on sandy soils, but on clayey soils a plastic bottom is preferred.

References cited

1 Lawrence, W. J. C.; Newell, J. Seed and potting composts. London, England: Allen and Unwin Ltd.; 1942.

2 Baker, K. F., editor. The U.C. system of producing healthy container-grown plants. Manual 23. Berkeley, CA; Univ. Calif. Agric. Exp. Stn; 1957.

3 Boodly, J. W.; Sheldrake, R., Jr. Cornell peat-lite mixes for commercial plant growing. Info. Bull. 43. Ithaca, NY: Cornell Univ.; 1973.

4 Maas, E. F.; Adamson, R. M. Soilless culture of commercial greenhouse tomatoes. Agric. Can. Publ. 1460; 1971, rev. 1980.

5 Maas, E. F.; Adamson, R. M. Resistance of sawdusts, peats and bark to decomposition in the presence of soil and nutrient solution. Soil Sci. Soc. Amer. Proc. 36:769–771; 1972.

6 Adamson, R. M.; Maas, E. F. Soilless culture of seedless greenhouse cucumbers and sequence cropping. Agric. Can. Publ. 1725 (in press).

7 Campbell, J. D. Peat moss for starting plants. MacDonald Coll. J. Ste Anne de Bellevue, P.Q.: MacDonald College; Nov. 1978.

8 Puustjarvi, V. Basin-peat culture. Peat and Plant News. 2:20–24; 1969.

9 B.C. Nursery Production Guide. Victoria, B.C.: B.C. Min. Agric.; 1980.

10 Mittleider, J. R. More food from your garden. Santa Barbara, CA: Woodbridge Press; 1975.

Selected references for further reading

Acta Horticulturae. Third symposium on peat in horticulture. The Hague, Netherlands: Tech. commun. Int. Soc. Hortic. Sci; 1972, Vol. 26: 1975, Vol. 50.

Bunt, A. C. Modern potting composts. London, England: Allen and Unwin Ltd.; 1976.

DeWerth, A. F.; Odom, R. E. A standard light-weight growing medium for horticultural specialty crops. Texas Agric. Exp. Stn; 1960.

McNeill, D. B. Composts and soil-less mixes for transplants. Ont. Min. Agric. and Food. Agdex 296/510; 1972.

Self, R. L.; Wear, J. I.; Rouse, R. D.; Orr, H. P. Potting mixtures and fertilization practices. Circular 157. Auburn, AL: Alabama Agric. Exp. Stn; 1967.

Appendix

Formula 1. Fertilizers required for a nutrient solution containing 126, 168, or 210 ppm of N, 37 ppm of P (84 ppm of P_2O_5), and 208 ppm of K (252 ppm of K_2O).

	Nitrogen levels in parts per million (ppm)*		
	126	168	210
		g/1000 L	
Potassium chloride (0-0-60)	420	250	nil
Potassium nitrate (13-0-46)	nil	225	550
Magnesium sulfate (Epsom salts)	500	500	500
Diammonium phosphate (21-53-0)	160	160	160
Calcium nitrate (15.5-0-0)	600	680	680
		mL/1000 L	
Minor-element solution**	220	220	220

* Parts per million = grams of nitrogen (N) per 1000 L.

** Saanichton minor-element mix is available commercially with iron in the chelated form. The chelated and citrate forms are prepared as follows:

	Iron chelate mix (grams)	Iron citrate mix (grams)	Minor elements in final nutrient solution
Iron	70.0 (10% iron)	42.0 (16.7% iron)	1.54 ppm Fe
Manganese sulfate	15.0	15.0	1.07 ppm Mn
Boric acid	12.0	12.0	0.46 ppm B
Zinc sulfate	2.2	2.2	0.11 ppm Zn
Copper sulfate	0.6	0.6	0.034 ppm Cu
Molybdic acid	0.2	0.2	0.023 ppm Mo
	100.0	72.0	

To prepare the minor-element stock solution, dissolve 100 g of dry iron chelate mix in 1 L warm water and store in dark bottle. If iron citrate mix is used dissolve 72 g in 1 L boiling water and store in dark bottle.

Formula 2. Fertilizers required for a nutrient solution containing 126, 168, or 210 ppm of N and 208 ppm of K (252 ppm of K_2O).

	Nitrogen levels in parts per million (ppm)		
	126	168	210
		g/1000 L	
Potassium nitrate (13-0-46)	550	550	550
Ammonium nitrate (34-0-0)	160	285	410
		mL/1000 L	
Minor-element solution*	220	220	220

*See Appendix, Formula 1

Formula 3. Proportions of ingredients required for a 14-7-21 hydroponic fertilizer.

Diammonium phosphate (21-53-0)	14.1% (by weight)
Potassium nitrate (13-0-46)	48.6%
Calcium nitrate (15.5-0-0)	35.4%
Minor-element mix with chelated iron (see Appendix, Formula 1)	1.9%

CONVERSION FACTORS

Metric units	Approximate conversion factors	Results in:
LINEAR		
millimetre (mm)	x 0.04	inch
centimetre (cm)	x 0.39	inch
metre (m)	x 3.28	feet
kilometre (km)	x 0.62	mile
AREA		
square centimetre (cm^2)	x 0.15	square inch
square metre (m^2)	x 1.2	square yard
square kilometre (km^2)	x 0.39	square mile
hectare (ha)	x 2.5	acres
VOLUME		
cubic centimetre (cm^3)	x 0.06	cubic inch
cubic metre (m^3)	x 35.31	cubic feet
	x 1.31	cubic yard
CAPACITY		
litre (L)	x 0.035	cubic feet
hectolitre (hL)	x 22	gallons
	x 2,5	bushels
WEIGHT		
gram (g)	x 0.04	oz avdp
kilogram (kg)	x 2.2	lb avdp
tonne (t)	x 1.1	short ton
AGRICULTURAL		
litres per hectare (L/ha)	x 0.089	gallons per acre
	x 0.357	quarts per acre
	x 0.71	pints per acre
millilitres per hectare (mL/ha)	x 0.014	fl. oz per acre
tonnes per hectare (t/ha)	x 0.45	tons per acre
kilograms per hectare (kg/ha)	x 0.89	lb per acre
grams per hectare (g/ha)	x 0.014	oz avdp per acre
plants per hectare (plants/ha)	x 0.405	plants per acre