

Appendix A

Rounded Atomic Weights

The listed atomic weights (A_r) mentioned below in this appendix are used in this book for the chemical calculations. They are withdrawn from Aylward G H and Findlay T J V (1974). SI Chemical Data, Second edition. John Wiley and Sons.

Name	Abbreviation	A_r
Aluminium	Al	27.0
Arsenic	As	74.9
Boron	B	10.8
Bromine	Br	79.9
Calcium	Ca	40.1
Cadmium	Cd	112.4
Carbon	C	12.0
Chlorine	Cl	35.5
Chromium	Cr	52
Copper	Cu	63.6
Fluorine	F	19.0
Hydrogen	H	1.0
Iodine	I	126.9
Iron	Fe	55.9
Lead	Pb	207.2
Magnesium	Mg	24.3
Manganese	Mn	54.9
Mercury	Hg	200.6
Molybdenum	Mo	95.9
Nickel	Ni	58.7
Nitrogen	N	14.0
Oxygen	O	16.0
Phosphorus	P	31.0
Potassium	K	39.1
Selenium	Se	79
Silicon	Si	28.1
Sodium	Na	23.0
Sulphur	S	32.1
Zinc	Zn	65.4

Appendix B

Guide Values for Tissue Analysis of Vegetables and Flower Crops

Optimum concentrations of mineral nutrients in greenhouse crops as given by De Kreij et al. (1992). The determinations are carried out by total destruction of dried material and expressed as mmol kg^{-1} dried material. For the references see Chapter 5.

Elements	Vegetables			
	Cucumber ¹	Sweet pepper ¹	Eggplant ¹	Radish ²
K	800–1000	1400–1800	1200–1300	1500
Ca	600–800	500–600	600–800	900
Mg	150–300	200–300	100–200	240
N	3000–4000	2500–3500	3500	4500
P	200–300	125–240	150–300	135
S	100	150–250	100	230
Fe	1.5–2.0	2.0–4.0	1.5	2.6–3.8
Mn	1.0–3.0	1.0–3.0	1.0–3.0	0.6–0.8
Zn	0.75–2.20	3.00	0.70–1.00	0.70–1.90
B	5.0–7.0	5.0–7.0	2.0–5.0	5.0–6.0
Cu	0.16	0.14–0.20	–	–
Mo	0.01–0.10	–	–	–

¹Young fully grown leaves;

²all leaves

Cut flowers						
Elements	Carnation ¹	Anthurium ²	Cymbidium ³	Gerbera ⁴	Bouvardia ⁴	Hippeastrum ⁴
K	800–1200	900–1000	600–750	1000–1280	500–850	1500
Ca	250–500	250–500	150–250	250–600	500–600	200–250
Mg	80–160	140–200	80–160	100–260	200–300	130
N	2000–3000	1400–1600	950–1450	1800–3500	3000–3500	2000–2200
P	60–200	50–100	50–100	80–200	200–300	90
S	–	70	–	–	100	–
Fe	1.0–2.0	0.5–2.0	0.5–1.0	1.0–2.0	2.3–4.0	1.0
Mn	0.6–5.5	0.7–2.0	0.55	0.7–2.7	0.6–1.7	1.0
Zn	0.30–1.50	0.70–2.00	0.30–0.80	0.5–0.8	0.60–1.00	0.60
B	2.0–9.0	5.0–7.0	2.0–6.5	2.8–3.7	3.0–5.0	3.0
Cu	0.10–0.20	0.10–0.20	0.08–0.16	0.06–0.20	–	0.10
Mo	–	–	–	–	–	–

¹Fifth pair of leaves of young shoots;

²leaves from just harvested flowers;

³second full grown leaf from young shoots;

⁴young fully grown leaves.

Elements	Potted flower plants ¹						
	Azalea	Begonia	Pelargonium	Saintpaulia	Cyclamen	Hydrangea	
K	200-500	500-750	640-1600	900-1500	1500	700-2000	
Ca	300-500	250-500	300-600	300-500	200	300-500	
Mg	70-135	150-250	80-210	250-350	125	100-250	
N	1400-1600	2500-3500	2350-3400	1500-2500	1800	1600-4000	
P	100-160	100-200	130-400	200-500	80	80-200	
S	-	-	-	-	-	-	
Fe	-	-	-	2.0-4.0	-	1.0-2.0	
Mn	-	-	0.8-2.5	0.5-2.0	0.9	0.7-1.7	
Zn	-	-	0.10-0.40	1.00-4.00	0.80	0.70-1.00	
B	-	-	-	4.0-10.0	5.0	2.0-3.0	
Cu	-	-	0.10-0.30	0.10-0.60	-	0.02-0.10	
Mo	-	-	-	-	-	-	

¹Young fully grown leaves.

Elements	Potted green plants ¹				
	Dieffenbachia	Ficus	Nephrolepis	Yucca	Hedera
K	1000–1600	550–750	500–800	600–800	900–1050
Ca	400–600	300–800	100–200	400–500	320–400
Mg	200–300	100–160	200–300	200–300	200–270
N	2400–2800	1600–2500	1500–1800	1000–1300	–
P	200–300	80–100	100–200	80–110	190–290
S	–	–	–	–	–
Fe	1.0–2.0	1.0–2.0	0.5–1.5	0.5–1.5	2.5–6.5
Mn	1.5–2.5	0.5–1.5	0.5–2.0	0.3–0.9	2.0–3.0
Zn	1.20–3.00	0.40–0.80	0.50–1.00	0.50–0.60	0.60–1.10
B	3.0–5.0	2.0–4.0	2.0–4.0	1.0–2.0	2.8–3.1
Cu	0.05–0.10	0.08–0.016	0.10–0.50	0.04–0.20	0.05–0.12
Mo	–	–	–	–	0.02–0.04

¹Young fully grown leaves

See also the data in Table 5.6.

Appendix C

Nutrient Solutions for Different Vegetable and Cut Flower Crops

Standard nutrient solutions (addition) as will be supplied for different crops and guide values for the chemical composition of the nutrient solutions in the root environment are published by De Kreij et al. (1999) and Sonneveld and Straver (1994). An extraction of such nutrient solutions is summarized in this appendix. For most crops different nutrient solutions will be given for free drainage systems and for closed systems. For free drainage a leaching fraction of about 0.3 is taken into account. For the references see Chapter 13.

	Tomato in rock wool			Cucumber in rock wool		
	Addition free drain	Addition closed	Root environment	Addition free drain	Addition closed	Root environment
EC dS m ⁻¹	2.6	1.6	4.0	2.2	1.7	3.0
NH ₄ mmol l ⁻¹	1.2	1.0	< 0.5	1.25	1.0	< 0.5
K	9.5	6.5	8.0	8.0	6.5	8.0
Ca	5.4	2.75	10.0	4.0	2.75	6.5
Mg	2.4	1.0	4.5	1.375	1.0	3.0
NO ₃	16.0	10.75	23.0	16.0	11.75	18.0
SO ₄	4.4	1.5	6.8	1.375	1.0	3.5
H ₂ PO ₄	1.5	1.25	1.0	1.25	1.25	0.9
Fe μmol l ⁻¹	15	15	25	15	15	25
Mn	10	10	7	10	10	7
Zn	5	4	7	5	5	7
B	30	20	50	25	25	50
Cu	0.75	0.75	0.7	0.75	0.75	1.5
Mo	0.5	0.5	0.5	0.5	0.5	0.5

	Sweet pepper in rock wool			Eggplant in rock wool		
	Addition free drain	Addition closed	Root environment	Addition free drain	Addition closed	Root environment
EC dS m ⁻¹	2.2	1.7	3.0	2.1	1.7	3.0
NH ₄ mmol l ⁻¹	0.75	0.75	< 0.5	1.5	1.0	< 0.5
K	6.5	5.75	5.0	6.75	6.5	6.2
Ca	5.0	3.5	8.5	3.25	2.25	6.2
Mg	1.5	1.125	3.0	2.5	1.5	4.5
NO ₃	15.5	12.75	17.0	15.5	11.75	20.0
SO ₄	1.75	1.0	3.0	1.5	1.125	3.0
H ₂ PO ₄	1.25	1.0	1.2	1.25	1.0	0.9
Fe μmol l ⁻¹	15	15	15	15	15	25
Mn	10	10	5	10	10	7
Zn	5	4	7	5	5	7
B	30	25	80	35	25	80
Cu	0.75	0.75	0.7	0.75	0.75	0.7
Mo	0.5	0.5	0.5	0.5	0.5	0.5

	Lettuce in circulating water		Chrysanthemum in circulating water	
	Addition	Root environment	Addition	Root environment
EC dS m ⁻¹	2.6	2.5	1.8	1.7
NH ₄ mmol l ⁻¹	1.25	< 0.5	1.25	< 0.5
K	11.0	6.0	7.5	5.0
Ca	4.5	7.0	2.5	3.5
Mg	1.0	1.5	1.0	1.5
NO ₃	19.0	19.0	12.75	10.0
SO ₄	1.125	2.0	1.0	2.0
H ₂ PO ₄	2.0	1.0	1.0	0.75
Fe μmol l ⁻¹	40	40	60	80
Mn	5	1	20	10
Zn	4	5	3	5
B	30	50	20	20
Cu	0.75	1	0.5	1.0
Mo	0.5	0.5	0.5	0.5

	Rose in rock wool			Gerbera in rock wool		
	Addition free drain	Addition closed	Root environment	Addition free drain	Addition closed	Root environment
EC dS m ⁻¹	1.6	0.7	2.2	1.7	1.1	2.2
NH ₄ mmol l ⁻¹	1.25	0.8	< 0.5	1.5	0.75	< 0.5
K	4.5	2.2	5.0	5.5	4.5	6.0
Ca	3.25	0.9	5.0	3.0	1.6	5.0
Mg	1.25	0.5	2.5	1.0	0.4	2.0
NO ₃	11.0	4.3	12.5	11.25	7.25	13.0
SO ₄	1.25	0.5	2.5	1.25	0.7	2.5
H ₂ PO ₄	1.25	0.5	0.9	1.25	0.6	1.0
Fe μmol l ⁻¹	25	15	25	35	25	40
Mn	5	5	3	5	5	3
Zn	3.5	3	3.5	4	3	5
B	20	15	20	30	20	40
Cu	0.75	0.5	1.0	0.75	0.5	1.0
Mo	0.5	0.5	0.5	0.5	0.5	0.5

	Cymbidium ¹		Anthurium ²	
	Addition free drain	Root environment	Addition Free drain	Root environment
EC dS m ⁻¹	0.8	0.8	0.8	1.0
NH ₄ mmol l ⁻¹	1.0(0.5)	< 0.5	0.5	< 0.5
K	2.8(3.0)	2.0	3.5	3.0
Ca	1.0(1.2)	1.5	1.25	2.0
Mg	0.75	1.0	0.9	1.3
NO ₃	4.0(4.5)	3.0	6.0	5.0
SO ₄	1.25(1.05)	1.5	0.8	1.25
H ₂ PO ₄	0.8	0.6	0.7	0.6
Fe μmol l ⁻¹	8	10	15	15
Mn	10	5	3	2
Zn	4	4	3	4
B	20	20	30	40
Cu	0.4	0.5	0.75	1.0
Mo	0.4	0.4	0.5	0.5

¹In rock wool or urethane foam granules; in brackets when phenol foam is used;

²in rock wool or foam granules.

	Potted plants in expanded clay granules		Hippeastrum in pumice	
	Addition free drain	Root environment	Addition free drain	Root environment
EC dS m ⁻¹	1.6	1.7	1.9	2.2
NH ₄ mmol l ⁻¹	1.1	< 0.5	1.25	< 0.5
K	5.5	4.5	7.0	6.5
Ca	3.0	4.0	3.0	5.0
Mg	0.75	1.0	1.0	2.0
NO ₃	10.6	9.5	12.5	16.0
SO ₄	1.0	2.0	1.25	2.0
H ₂ PO ₄	1.5	1.0	1.25	1.0
Fe μmol l ⁻¹	20	15	10	15
Mn	10	5	10	7
Zn	3	4	5	7
B	20	40	30	50
Cu	0.5	0.75	0.75	1.0
Mo	0.5	0.5	0.5	0.5

Appendix D

Nutrient Solutions and Guide Values for the 1:1½ Extract Recommended for Potted Plants

The crops are classified in different groups and some characteristic potted plants species, representative for the groups are added. The data are derived from Straver et al. (1999). See Chapter 14 for this reference.

Group 1				
	Nutrient solution		1:1½ extract	
	Veg. + Gen. ¹		Veg. + Gen.	
			Crops	
EC ds m ⁻¹	0.5		0.40	<i>Dionea</i>
NH ₄ mmol l ⁻¹	0.4		< 0.1	<i>Drosera</i>
K	1.8		1.0	<i>Asplenium</i>
Ca	1.0		0.8	<i>Cereus</i>
Mg	0.25		0.3	<i>Echinocactus</i>
NO ₃	3.5		1.5	<i>Opuntia</i>
SO ₄	0.35		0.4	(approx. 20
H ₂ PO ₄	0.5		0.5	species)

¹Veg.-vegetative growth phase; Gen.-generative growth phase.

Group 2					
	Nutrient solution		1:1½ extract		Crops
	Veg.	Gen.	Veg.	Gen.	
EC ds m ⁻¹	1.0	1.0	0.50	0.50	<i>Chamaedorea</i>
NH ₄ mmol l ⁻¹	0.8	0.6	< 0.1	< 0.1	<i>Neoregelia</i>
K	3.7	4.4	1.2	1.3	<i>Osteospermum</i>
Ca	2.0	1.7	1.0	0.9	<i>Phalaenopsis</i>
Mg	0.5	0.5	0.3	0.3	<i>Saintpaulia</i>
NO ₃	7.1	6.0	2.5	2.0	<i>Tagetes</i>
SO ₄	0.7	1.2	0.6	1.0	<i>Verbena</i>
H ₂ PO ₄	1.0	1.0	0.5	0.5	(approx. 280
					species)

Group 3

	Nutrient solution		1:1½ extract		Crops
	Veg.	Gen.	Veg.	Gen.	
EC dS m ⁻¹	1.5	1.4	0.70	0.65	<i>Anthurium</i>
NH ₄ mmol l ⁻¹	1.1	1.0	< 0.1	< 0.1	<i>Areca</i>
K	5.5	5.5	1.6	1.6	<i>Calathea</i>
Ca	3.0	2.5	1.2	1.0	<i>Cordyline</i>
Mg	0.75	0.75	0.5	0.5	<i>Primula</i>
NO ₃	10.9	8.5	4.0	3.0	<i>Dracaena</i>
SO ₄	1.1	1.75	0.8	1.4	<i>Hedera</i>
H ₂ PO ₄	1.0	1.0	0.5	0.5	<i>Fuchsia</i> <i>Kalanchoe</i> <i>Zamioculcas</i> (approx. 250 species)

Group 4

	Nutrient solution		1:1½ extract		Crops
	Veg.	Gen.	Veg.	Gen.	
EC dS m ⁻¹	2.0	1.5	0.90	0.75	<i>Bougainvillea</i>
NH ₄ mmol l ⁻¹	1.4	1.0	< 0.1	< 0.1	<i>Clerodendrum</i>
K	7.3	6.5	2.4	2.5	<i>Chrysanthemum</i>
Ca	4.0	2.5	1.4	1.0	<i>Hibiscus</i>
Mg	1.0	0.75	0.6	0.5	<i>Petunea</i>
NO ₃	14.1	9.0	6.0	3.5	<i>Pelargonium</i>
SO ₄	1.3	1.75	1.0	1.4	(approx. 20
H ₂ PO ₄	2.0	1.5	0.5	0.5	species)

Group 5

	Nutrient solution		1:1½ extract		Crops
	Veg. + Gen.		Veg. + Gen.		
EC dS m ⁻¹	1.4		0.70		<i>Vriesea</i>
NH ₄ mmol l ⁻¹	1.0		< 0.1		<i>Aechmea</i>
K	6.5		2.4		
Ca	2.25		1.0		
Mg	0.75		0.5		
NO ₃	9.5		3.5		
SO ₄	1.25		1.0		
H ₂ PO ₄	1.5		0.5		

Group 6

	Nutrient solution		1:1½ extract		Crops
	Veg.	Gen.	Veg.	Gen.	
EC dS m ⁻¹	0.6	0.6	0.35	0.30	<i>Erica</i>
NH ₄ mmol l ⁻¹	1.5	1.5	< 0.1	< 0.1	<i>Rhododendron</i>
K	1.2	1.6	0.6	0.8	
Ca	1.2	1.0	1.0	0.5	
Mg	0.45	0.45	0.3	0.3	
NO ₃	4.95	4.95	2.5	1.5	
SO ₄	0.35	0.35	0.3	0.3	
H ₂ PO ₄	0.35	0.35	0.2	0.2	

Group 7

	Nutrient solution		1:1½ extract		Crops
	Veg.	Gen.	Veg.	Gen.	
EC dS m ⁻¹	1.5	1.5	0.70	0.70	<i>Begonia</i>
NH ₄ mmol l ⁻¹	1.25	1.25	< 0.1	< 0.1	
K	3.5	4.0	1.6	2.0	
Ca	4.0	3.75	1.2	1.0	
Mg	0.75	0.75	0.7	0.7	
NO ₃	11.65	11.65	4.0	4.0	
SO ₄	0.8	0.8	0.6	0.6	
H ₂ PO ₄	1.0	1.0	0.5	0.5	

Group 8

	Nutrient solution		1:1½ extract		Crops
	Veg. + Gen.		Veg. + Gen.		
EC dS m ⁻¹	1.6		0.70		<i>Euphorbia</i>
NH ₄ mmol l ⁻¹	2.25		< 0.1		<i>pulcherrima</i>
K	3.5		1.6		
Ca	3.75		1.4		
Mg	1.0		0.6		
NO ₃	12.25		4.0		
SO ₄	1.0		0.8		
H ₂ PO ₄	1.0		0.5		

Group 9							Crops
Nutrient solution			1:1½ extract				
Veg. S. ¹	Veg. W. ¹	Gen. W.	Veg. S.	Veg. W.	Gen. W.		
	Gen. S.			Gen. S.			
EC dS m ⁻¹	2.1	1.5	1.4	1.10	0.90	0.65	<i>Ficus</i>
NH ₄ mmol l ⁻¹	1.4	1.1	1.0	< 0.1	< 0.1	< 0.1	
K	7.3	5.5	5.5	4.0	3.0	1.6	
Ca	4.0	3.0	2.5	2.0	1.7	1.0	
Mg	1.0	0.75	0.75	0.7	0.6	0.5	
NO ₃	14.5	10.9	8.5	7.5	6.0	3.0	
SO ₄	1.6	1.1	1.75	1.5	1.0	1.4	
H ₂ PO ₄	1.0	1.0	1.0	0.5	0.5	0.5	

¹S.-summer; W.-winter.

Group 10				
	Nutrient solution		1:1½ extract	
	Veg. + Gen.		Veg. + Gen.	
			Crops	
EC dS m ⁻¹	1.0		0.70	<i>Chrysalidocarpus</i>
NH ₄ mmol l ⁻¹	0.8		< 0.1	
K	3.7		1.6	
Ca	2.0		1.2	
Mg	0.5		0.5	
NO ₃	7.1		4.0	
SO ₄	0.7		0.8	
H ₂ PO ₄	1.0		0.5	

Group 11					
	Nutrient solution		1:1½ extract		Crops
	Veg.	Gen.	Veg.	Gen.	
EC dS m ⁻¹	2.0	1.5	0.90	0.75	<i>Spathiphyllum</i>
NH ₄ mmol l ⁻¹	1.4	1.0	< 0.1	< 0.1	
K	7.3	6.0	2.3	2.5	
Ca	4.0	2.5	1.4	1.2	
Mg	1.25	1.0	1.5	1.0	
NO ₃	14.1	9.0	5.0	4.0	
SO ₄	1.8	2.0	1.0	1.4	
H ₂ PO ₄	1.5	1.0	0.8	0.7	

Micro element recommendation for potted plants, the standards for the nutrient solution supplied, and the guide values in the 1:1½ by volume extract with the range within no adjustments are recommended for the nutrient solution supplied. Concentrations expressed as $\mu\text{mol l}^{-1}$

	Nutrient solution supplied	1:1½ extract	
		Guide values	Range accepted
Fe	15	8	5–10
Mn	5	2	1–3
Zn	3	2	1.5–2.5
B	10	15	10–25
Cu	0.5	0.7	< 0.9
Mo	0.5	nd ¹	nd ¹

¹nd = not defined

Appendix E

Guide Values for Soil Grown Crops

Guide values for the analytical data of the 1:2 volume extract for the base dressing. See also the data in Table 16.8

Crops	K	Ca	Mg	N	SO ₄	P	Cl
	mmol l ⁻¹						
Lily (Asian type)	1.0	1.5	0.8	2.0	1.5	0.10	
Lily (non Asian)	1.3	1.8	1.0	3.0	1.3	0.10	
Hippeastrum	1.3	1.5	1.0	2.5	1.5	0.10	
Carnation	1.5	2.5	1.2	4.0	1.5	0.10	
Cucumber	1.8	2.2	1.2	4.0	1.5	0.10	
Sweet pepper	2.0	2.5	1.2	4.5	2.0	0.10	
Eggplant	1.8	2.0	1.5	4.5	2.0	0.10	
Lettuce ¹	2.5	3.25	1.0	4.0	3.5	0.10	
Lettuce ²	3.0	3.25	1.0	5.0	3.5	0.10	2.0

¹March 15th–August 15th;

²August 15th–March 15th.

Guide values for the analytical data of the 1:2 volume extract maintained during crop cultivation. See also the data in Table 16.10

Crops	K	Ca	Mg	N	S	EC
	mmol l ⁻¹					dS m ⁻¹
Chrysanthemum	1.0	1.5	0.8	2.0	1.5	0.8
Rose	1.5	2.0	1.2	4.0	1.5	1.0
Hippeastrum	1.3	1.5	1.0	2.5	1.5	0.8
Carnation	1.5	2.5	1.2	4.0	1.5	1.2
Cucumber	1.8	2.2	1.2	4.0	1.5	1.0
Sweet pepper	2.0	2.5	1.2	4.5	2.0	1.1
Eggplant	1.8	2.0	1.5	4.5	2.0	1.2

Composition of nutrient solutions used with fertigation of soil grown crops irrigated with sprinkler irrigation systems. For drip irrigation the concentrations will be increased by 25%

Crops	NH ₄	K	Ca	Mg	NO ₃	SO ₄	EC _{irr} ¹
	mmol l ⁻¹						dS m ⁻¹
Chrysanthemum	0.3	3.2	1.6	0.8	6.7	0.8	0.83
Rose	0.7	2.6	1.5	0.8	6.3	0.8	0.79
Hippeastrum	0.2	3.0	1.2	1.0	5.8	1.0	0.76
Carnation	0.3	3.2	1.6	0.8	6.7	0.8	0.83
Tomato	0.3	3.6	1.4	1.1	6.7	1.1	0.89
Cucumber	0.7	2.6	1.5	0.8	6.3	0.8	0.79
Sweet pepper	0.3	3.2	1.6	0.8	6.7	0.8	0.83
Eggplant	0.7	2.6	1.5	0.8	6.3	0.8	0.79

¹Except the possible residual salts in the irrigation water.

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