SUCCESSFUL GARDENING WITHOUT SOIL

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by

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Hon. Sec. Soilless Culture Society

With a Foreword by
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1956
CHEMICAL PUBLISHING Co., Inc.
212 FIFTH AVENUE NEW YORK, N.Y.

Successful Gardening Without Soil

ISBN: 978-0-8206-0124-3

Chemical Publishing Company:
www.chemical-publishing.com
www.chemicalpublishing.net

First American Edition:
Chemical Publishing Company, Inc. - New York 1956
Second Impression:
Chemical Publishing Company, Inc. - 2011

Printed in the United States of America

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(*Between pages 72 and 73*)

FOREWORD

By Professor R. H. STOUGHTON, D.SC.

THE idea of the application of the sand- and water-culture methods of plant physiologists to the practical growing of plants by the amateur and the commercial grower has passed through the stages of incredulity, enthusiasm, derision, scepticism, and finally to sober acceptance, since the first proposals of Dr. F. Gericke in 1936. What was for long a stunt has become almost a commonplace in a surprisingly short time, so that now there is nothing remarkable in hearing that a grower with some acres of glass has turned over wholly or mainly to nutrient solution cultivation in sand or gravel.

This is not to say, however, that there is not still much to be learnt in this new application of scientific method. Unexpected, or at least unforeseen, difficulties and even disasters occur, all the worse in that if anything does go wrong all the plants under the same treatment are likely to be affected, instead of, as in soil, perhaps only a few in one bed. But with increasing experience and research these troubles can be guarded against or sometimes overcome after they have started, though in this as with all gardening matters, prevention is far better than cure.

Let no one fall into the trap of thinking that these methods are foolproof or even easier than the age-old ways of growing in soil. It must always be remembered that the plant itself is still the same; knowledge of its habits, its needs for particular light and temperature conditions, the pests and the diseases which may attack it, in short, its management, is no less necessary than before. After all, soilless cultivation is but an attempt to achieve one more step towards the goal of all good gardeners and plant research workers, control over the conditions under which the plant grows, its environment, to the betterment of man's profit or aesthetic enjoyment.

Although, therefore, to attain success with solution culture one must have at least as much knowledge and experience of the growing of the particular plant as ever, yet much of the factual aspect of the systems, the "know-how," can be acquired from books. The author of this book, himself an enthusiastic practitioner of soilless cultivation, has put down from his own experience and that of others a clear account of the principles and practice of the methods, which will start the feet of the beginner on the right path and save him from many pitfalls. Though an enthusiast, he does not allow his fervour to cloud his judgment and he courageously draws attention to the views of some of the decriers before he begins his own instructions.

Not only the beginner but the established grower also will find much of interest and guidance in these pages, set out with clarity and simplicity so that one need not be a chemist to understand the making-up of solutions or a plant physiologist to learn something of deficiency disorders, though one must still and ever be a gardener. However great may be advances in scientific knowledge of chemical testing, temperature control, light and moisture requirements and so on, yet the plant itself remains a living organism which can tell its own tale to the initiated better than any instrument.

PREFACE

In the days when nurserymen were not as scrupulous as they are today, the best produce was sometimes found on top of the basket and the worst below. The indignant buyer then formed an immediate opinion of the seller, and went off to try someone else.

Something of the same sort seems to be in danger of happening with soilless culture. With more enthusiasm than wisdom, a number of writers have emphasised the advantages and glossed over the difficulties. Keen gardeners have been led to take up the new method of growth without being warned of the pitfalls. In contrast with the few who have persisted and won through, many have given the whole thing up in despair.

This is unfortunate. Soilless culture *has* real advantages. It *does* work—and work well, provided it is done properly. But the newcomer must realise at the outset that it is more difficult to produce results than with soil. There are many more factors which may go wrong.

So before you begin this book, I warn you I have turned the basket upside down and shown you the worst first. I have tried never to gloss over a difficulty or drawback.

But if, realising these limitations, you go on, you will find many unexpected rewards—including the thrill of achieving Nature's purpose in a way that only those who live in this modern age can know.

C. E. T.

1

THE BEGINNINGS

THE Americans are the biggest exponents of soilless culture today. But everybody seems agreed that it was an Englishman, John Woodward, who started growing plants without soil. In 1699 he cultivated them in various kinds of water to which he added garden soil. His most celebrated experiment was with spearmint. With this he managed to prove that it was earth and not water that made plants grow.

It was more than a hundred years before the subject was systematically studied again. Then a Frenchman, De Saussure, put forward in 1804 the idea that plants were made up of elements extracted from water, soil, and air.

Another Frenchman, chemist Jean Boussingault, found that the carbon and oxygen in growing tissues came from the air, and the hydrogen from water. The fact that nitrogen was contained in plants was also discovered by him.

Sachs and Knop, however, were the real pioneers of nutrient solutions as we understand them today. They germinated seeds on muslin tied over small jars, feeding the roots with chemical solutions. Those same methods, with a few improvements, are used in botanical laboratories today.

The seed-and-jar method showed that, to grow properly, a plant solution must contain nitrogen, potassium, phosphorous, magnesium, calcium, and sulphur.

Those six elements are now called the major elements, or if you want to be a little more technical, macro-nutrients.

Later it was discovered that in addition to the six macro-nutrients, iron was vital to growth. Then manganese, boron, copper, zinc, and—quite recently—molybdenum were all found to be essential. As only very small amounts—or traces—of these elements were needed, they were called the trace, or minor, elements. Another term used is micro-nutrients.

Many of these elements are always present even in pure chemicals, so it was a long and complicated process to prove that plants died without them. In some cases a single seed contained enough to last a plant for more than one generation. But, proved it was, and today we use the knowledge gained by the patience of our predecessors.

Nor is the end anywhere in sight. If they can only devise methods exact enough, the scientists will probably be able to prove sooner or later that uranium (of atom fame), vanadium, selenium, and a host of other obscure elements found in plant tissue are there for a purpose, and not by chance. Already aluminium, silicon, chlorine, and gallium are *almost* on the "essential" list.

Fortunately for those who just want to grow a few plants without soil—and without too much trouble—there are enough of all these "iums" in the fertiliser-grade salts usually used. So having mentioned them, we can forget them.

Not until the early 1920's did it occur to anyone that amateur and commercial crop production might be feasible without soil.

It was Dr. W. F. Gericke of California who in 1929 took the great step of bringing water culture out of the laboratory into the greenhouse and garden.

The results of the Gericke system were remarkable.

The Press took up the theme—with variations. Amateur enthusiasts got busy all over America, and in Europe, too. Misguided experimenters (myself included) threw a handful of chemicals into a jar or tin, filled up from the kitchen tap, and sat back to watch the "miracle". Of course, nothing happened.

What went wrong? Nothing, really. Dr. Gericke *did* get astonishing results—but under a Californian sun. His tomatoes *did* require a ladder to pick them—but with warm solution, and under the guidance of a super-expert.

Hard on the heels of water culture, but without all the publicity, came sand culture. This was easier, and cheaper, and altogether more understandable to the grower who had been used to soil. But it had its drawbacks. The labour of watering was one.

Labour-saving was the thought behind the introduction of beds of gravel or cinders fed automatically by solution pumps. This was eminently suited to operations on a big scale, and when difficulties of providing troops scattered in tropic outposts with fresh vegetables led the United States Air Force to take up soilless culture to save shipping space, it was this system that was used. In 1945 the first big installation was laid down on Ascension Island. Then the world's biggest installation of some eighty acres was put into operation in Japan.

Since the war a new system of feeding beds by solution flowing along channels, or flumes, has been evolved. It is cheaper to instal than piping, and is becoming steadily more popular.

Which brings our rather sketchy history up to the present day.

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WATER

THERE are three ways of growing plants without soil:

1. Water culture, usually known as hydroponics.
2. Sand culture.
3. Sub-irrigation, in which gravel, cinders, pumice, or several other materials consisting of small solid particles may be used.

The one thing common to all these is water. Yet it is the water which the average would-be grower forgets. Drinkable water is well-nigh universal in the British Isles, and so we hardly ever give it a thought. Yet it is a fact that there is almost as much difference between some samples of water and others as there is between chalk and cheese. These differences may be important to anyone using the water for soilless culture.

So I advise you, if you are only doing things in a small way in the greenhouse or on the front-room window-ledge, to use rain water. It is easy to collect, by putting a barrel or old tank under a gutter-spout. If you have a greenhouse you probably collect it for watering the plants in any case.

If you are doing things on a bigger scale, and have to use water from the mains or from a well or stream, then there is only one safe thing to do—find out what the supply contains.

Our water system is looked after by a series of undertakings who draw from hills or rivers all over the country. Sometimes it is a corporation or council, sometimes a water board or similar body. What you have to do is to find out who actually supplies the water you use, and then write to the engineer or analyst concerned. They have to make regular analyses in the ordinary course of events, and are usually quite happy to tell you what they are.

Here is a typical one, in this case for the City of Birmingham:

Calcium	0·5	
Sodium	0·5	
Magnesium	0·2	
Potassium	0·1	
Iron	0·1	
Bicarbonate	1·3	
Chlorine	0·8	
Sulphate	0·6	
Silicate	0·3	
Undetermined	0·1	
	4·5	parts per 100,000

Soilless culture solutions are usually worked out in parts per million cubic centimetres, so if we multiply those figures by ten we get the right amounts for our calculations.

Four of the elements given above are directly concerned in our solutions—calcium, magnesium, potassium, and iron. Let us take one example to show how the analysis affects us. Suppose we are using a solution containing 150 p.p.m. of potassium. The above figures show that there is only one (0·1 × 10) part per million

APPENDIX

METRIC TABLES

Table of Length

(Km)	1 Kilometre	equals	1,000	metres
(Hm)	1 Hektometre	,,	100	metres
(Dm)	1 Dekametre	,,	10	metres
(m)	1 Metre	,,	100	cm. or 1,000 mm.
(dm)	1 decimetre	,,	0·1	metre
(cm)	1 centimetre	,,	0·01	metre
(mm)	1 millimetre	,,	0·001	metre

Table of Weight

(Kg)	1 Kilogram	equals	1,000	grams
(Hg)	1 Hektogram	,,	100	grams
(Dg)	1 Dekagram	,,	10	grams
(g)	1 gram	,,	weight of 1 c.c. water or 1,000 mg.	
(dg)	1 decigram	,,	0·1	gram
(cg)	1 centigram	,,	0·01	gram
(mg)	1 milligram	,,	0·001	gram

Table of Capacity

(Kl)	1 Kilolitre	equals	1,000	litres
(Hl)	1 Hektolitre	,,	100	litres
(Dl)	1 Dekalitre	,,	10	litres
(l)	1 litre	,,	1,000	cub. centimetres
(dl)	1 decilitre	,,	0·1	litre (100 c.c.)
(cl)	1 centilitre	,,	0·01	litre (10 c.c.)
(ml)	1 millilitre	,,	0·001	litre (1 c.c.)

It will be readily seen from the above table that 1 milligram of substance dissolved in 1 litre of water gives 1 part per million (1 p.p.m.) of that substance in water (or 1 gram in 1,000 litres).

CONVERSION TABLES

1. *Linear Measure*

Imperial		*Metric*	
1 inch	25·4 mm.	1 mm.	0·039 in.
1 foot	0·305 m.	1 cm. (10 mm.)	0·394 in.
1 yard	0·9144 m.	1 dm. (10 cm.)	3·937 in.
1 mile	1·609 km.	1 m.	39·370 in. 3·281 ft. 1·093 yds.
		1 km	0·621 mile

2. *Square Measure*

Imperial		*Metric*	
1 sq. in.	6·451 sq. cm.	1 sq. cm.	0·155 sq. in.
1 sq. yd.	0·836 sq. m.	1 sq. m.	10·764 sq. ft.
			1·196 sq. yds.

3. *Cubic Measure*

Imperial		*Metric*	
1 cub. in.	16·387 cub. cm.	1 cub. cm.	0·061 cub. in.
		1 cub. cm.	61·024 cub. in.
1 cub. ft.	0·038 cub. m.	1 cub. m.	35·315 cub. ft.
1 cub. yd.	0·764 cub. m.		1·308 cub. yds.

4. *Measure of Weight*

Imperial		*Metric*	
1 oz.	28·3 grams.		
1 lb.	0·454 kg.	1 kg.	2·204 lb.
1 ton	1,016 kg.		

5. *Measures of Capacity*

Imperial		*Metric*	
1 pint	0.568 l.	1 l.	1·759 pints
1 gallon	4·546 l.		·22 gal.
		1 hl.	175·98 pints
			21·997 gals.

To convert yards to metres, multiply by 0·914.
To convert gallons to litres, multiply by 4·54.
To convert litres to gallons, multiply by 0·22.

ATOMIC WEIGHTS

The following table of atomic weights refers only to those elements most generally used in soilless culture.

Element	*Symbol*	*Atomic weight*	
		Exact	*Approximate*
Aluminium	Al	26·97	27
Boron	B	10·82	11
Calcium	Ca	40·08	40
Carbon	C	12·01	12
Chlorine	Cl	35·457	35
Copper	Cu	63·57	64
Hydrogen	H	1·0078	1
Iron	Fe	55·84	56
Magnesium	Mg	24·32	24
Manganese	Mn	54·93	55
Nitrogen	N	14·008	14
Oxygen	O	16·0	16
Phosphorus	P	31·02	31
Potassium	K	39·096	39
Silicon	Si	28·06	28
Sodium	Na	22·997	23
Sulphur	S	32·06	32
Zinc	Zn	65.38	65

CONVERSION FACTORS

1 inch = 2·54 c.m.
1 c.m. = 0·394 inch
1 pound = 453·6 grams

To convert yards to metres, multiply by 0·914

To convert lb. avoirdupois to kilograms, multiply by 0·454

To convert gallons to litres, multiply by 4·54

To convert ounces to grams, multiply by 28·3

MISCELLANEOUS USEFUL FACTORS

1 litre = 0·88 quart or 1·76 pints.

Ounces per gallon multiplied by 6·25 = grams per litre.

Grams per litre multiplied by 1·6 = ounces per 10 gallons.

One U.S. gallon = 0·833 Imperial gallon.

1 Quart weighs roughly 4 oz. avoirdupois.

1° Centigrade = 1·8° Fahrenheit.

1 Cubic foot = $6\frac{1}{4}$ gallons.

To convert weight of 50% calcium nitrate solution into measure of capacity, multiply by $^4/_3$.

TWO SUGGESTED FORMULÆ FOR BEGINNERS*

Salt	*Amount in ounces*	*In level teaspoonful*
Potassium phosphate	½	1
Potassium nitrate	2	4
Calcium nitrate	3	7
Epsom salts	1½	4
Water	20 gallons	
Ammonium phosphate	½	2
Potassium nitrate	2½	5
Calcium nitrate	2½	6
Epsom salts	1½	4
Water	20 gallons	

To each of these solutions, the usual trace elements have to be added.

*Originated by California Agricultural Experiment Station.

†THE W.P. FORMULA

	Grams per 1,000 litres
Potassium nitrate	608
Gypsum	1,214
Epsom salts	511
Monocalcium phosphate (food grade)	282
Ammonium sulphate	110
	2,725 grams

†Developed by A. Wagner & G. Poesch, Ohio Agricultural Experiment Station.

FORMULÆ WHICH CAN BE MIXED DRY

Simplified Formula for Amateur use:

Potassium nitrate	1 oz.
Monocalcium phosphate	½ oz.
Magnesium sulphate	¾ oz.
Ferrous sulphate	1 teaspoonful
Rain water	4¼ gallons

*Commercial Use**

	Grams per 1,000 litres
Potassium nitrate	1,100
Gypsum	760
Epsom salts	520
Monocalcium phosphate (treble super)	310
Ammonium sulphate	140
Total weight as complete mix	2,830 grams

*For Calcareous aggregates**

	Grams per 1,000 litres
Potassium nitrate	1,100
Magnesium sulphate†	520
Ammonium phosphate (fertiliser grade)	280

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*From *Nutriculture*, the U.S. War Department manual.

†This may require to be reduced or left out if any appreciable quantity of magnesium is found in the aggregate.

GUIDE TO PREPARATION OF NUTRIENT SOLUTIONS*

Chemical	*Fraction of one ounce required per 100 gallons to give 1 p.p.m. of element specified.*
Sodium nitrate	0·103 N
Calcium nitrate	0·135 N also 1·4 p.p.m. Ca
Ammonium sulphate	0·076 N
Potassium nitrate (for N)	0·122 N also 2·8 p.p.m. K
Potassium nitrate (for K)	0·044 K also 0·36 p.p.m. N
Potassium sulphate	0·040 K
Potassium chloride (muriate)	0·033 K
Superphosphate (16% sol P_2O_5)	0·268 P also 3·8 p.p.m. Ca
Monocalcium phosphate	0·076 P also 0·6 p.p.m. Ca
Monopotassium phosphate	0·07 P 0·056 K
Magnesium sulphate (Epsom salts)	0·172 Mg
Ferrous sulphate	0·089 Fe
Calcium sulphate (gypsum)	0·076 Ca
Calcium sulphate (plaster of Paris)	0·027 Ca
Manganese sulphate	0·065 Mn
Boric acid	0·090 B
Ferric ammonium citrate	0·138 Fe
Diammonium phosphate	0·095 P
Magnesium nitrate	0·13 Mg.

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*Based on a table issued by Prof. R. H. Stoughton, D.Sc., of Reading University.

MOLECULAR WEIGHTS

Including usual percentage of impurities

Salt	*Formula*	*Molecular Weight*
Ammonium sulphate	$(NH_4)_2SO_4$	140
Sodium nitrate	$NaNO_3$	90
Potassium nitrate	KNO_3	110
Calcium nitrate	$Ca(NO_3)_2.H_2O$	260
Calcium nitrate (pure form)	$Ca(NO_3)_2$.	180
Potassium sulphate	K_2SO_4	200
Potassium chloride	KCL	80
Monocalcium phosphate (super)	—	750
Monocalcium phosphate (treble super)	$CaH_4(PO_4)_2.H_2O$	310
Monocalcium phosphate (food grade)	$CaH_4(PO_4)_2.H_2O$	270
Monopotassium phosphate	KH_2PO_4	140
Magnesium sulphate (Epsom salts)	$MgSO_4.7H_2O$	260
Magnesium sulphate anhydrous	$MgSO_4$	130
Calcium sulphate (plaster of Paris)	$CaSO_4$	190
Calcium chloride	$Ca\ Cl_2$	150
Ammonium phosphate	$NH_4H_2PO_4$	140
Ammonium phosphate (food grade)	$NH_4H_2PO_4$	120
Magnesium nitrate	$Mg(NO_3)_2.6H_2O$	256

RELATIONS OF ANTAGONISM

(The elements, an excess of which will inhibit the uptake of other elements).

Except in the case of those underlined, the first element inhibits the uptake of the second. In the underlined cases it assists the uptake.

N/K	*N/P*	$\underline{N/Mg}$			
K/Mg	$\underline{K/Fe}$	*K/Mn*	*K/Ca*	*K/Mg*	*K/N*
Mg/Ca	*Mg/K*	*Mg/N*			
Na/Ca					
Ca/Mn	*Ca/B*	*Ca/N*	*Ca/K*	*Ca/Mg*	
P/Zn					
Mn/Fe	Heavy metals/*Fe*				
Fe/Mn					

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