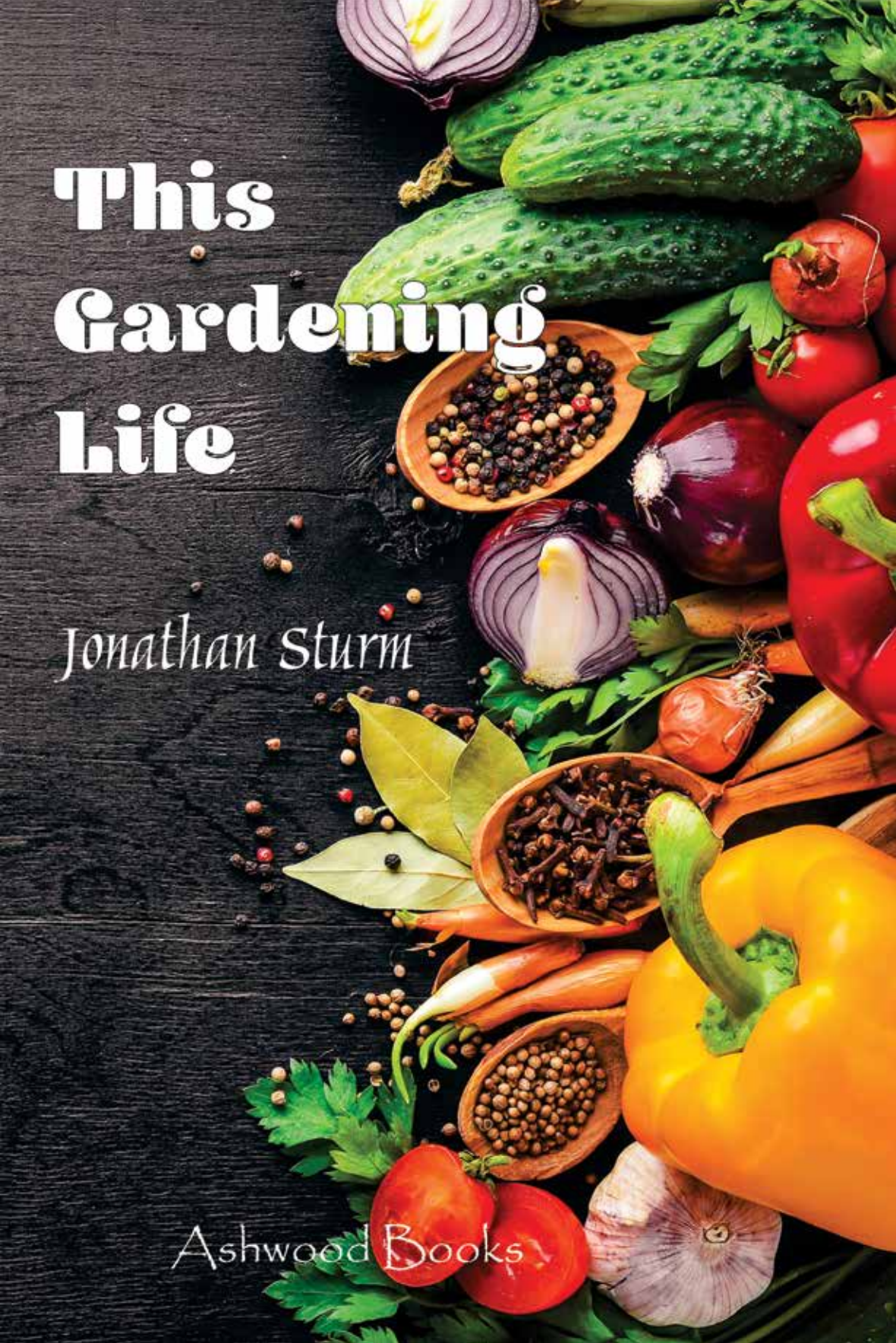
This Gardening Life
Jonathan Sturm
Ashwood Books

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This cabbage, these carrots, these potatoes, these onions… will soon become me. Such a tasty fact!
—Mike Garofalo

In memory of my parents: my father the gardener and my mother the Stoic.

I've had a good life, and was born to and among people I've admired and loved.

—Wendell Berry

Contents

Gardening is seen as a pastime that is almost like belonging to the Church of England—a sign of maturity and wisdom and right thinking.

—Monty Don

A Sufi Story (of sorts)

Many years ago in a land far away, there was a little village that was famous throughout the world for the quality of its wine. For countless generations, year after year, the peasants who grew the grapes and made the wine held a harvest festival in their little church. There they would give thanks to God for blessing them with the grapes that made their wonderful wine. The priest would bless the puncheon of the very best of their wine and dispense a flagon of it to each of the peasants whose vineyards contributed to their main source of income. Each peasant would then sprinkle the contents of their flagon along the rows of grapevines as a thank you to the ancient goddess Demeter.

Then one year the village was sent a new priest to replace their rather old and tired one who had retired to Rome. This young man had been well-educated rather than a rustic like his predecessor. He knew all about science and industry having been taught such things at university. He realised that the puncheon of the best wine could be sold at Rome for a very good price and that the extra fame that this brought would doubtless mean an even better price for the village's wines in the market. Indeed this turned out to be so.

For several years the villagers benefited from the extra income they now had, but slowly, ever so slowly, the quality of their wine diminished. It no longer tasted better than every wine in the land. Eventually, it was no better than the ordinary stuff you could buy anywhere and the price they received reflected that. For while the villagers had believed they were thanking Demeter by sprinkling their best wine throughout their vineyards, they had been inoculating their grapes with a particular strain of yeast that was responsible for the extraordinary quality of their wine. Without annual refreshment following the harvest festival, that strain had gradually been replaced by inferior strains of yeast.

Do not seek to bring things to pass in accordance with your wishes, but wish for them as they are, and you will find them.

—Epictetus

Preamble

Asking the question: "Why grow your own vegetables?" elicits a number of responses. The most important from my point of view is *flavour*. While the initial impetus was the idea of self-sufficiency, it was the taste of what I was growing that kept me growing vegetables until severe arthritis rendered it almost impossible to continue. You will read further on about how my peas were the cause of my taking up market gardening.

I have always enjoyed doing and making things for myself, not always successfully. Gardening is far and away the most popular recreational activity in Australia and it would not surprise me if that's true of the whole world. There's more than one aspect to this. Some enjoy the aesthetic aspect: what the results look like. Others enjoy cooking and eating. I love both of these activities and I am renowned for the excellence of my dinner parties.

Knowing how your vegetables were grown is important to many. Garlic from the supermarket may have been treated with a chemical to inhibit sprouting, the silver beet may have been forced with water-soluble nitrogen fertiliser and so be full of nitrosamines, a toxic substance. I knew one apple grower who was still using DDT 30 years after it had been banned in Australia.

Growing your own vegetables can save you a great deal of money. Not a great deal if you grow to supermarket quality, but the major purchasers of the best quality produce are gourmet chefs and they pay top dollar. I have never eaten purchased vegetables of that quality from a shop, or farmer's market for that matter, but my wife once commented while we ate a meal we had prepared: "I wonder what the poor rich people are having to eat tonight".

Gardening for 45 minutes provides the same amount of exercise as running 2.4 kilometres (1½ miles).[1] Some of us find gardening to be more fun than running and I'm not sure who'd buy the product of someone running whatever that might be! Like running, the physical activity of gardening reduces stress and relieves tension. I believe that's what diazepam (Valium) is for.

The waste from purchased food (20%) generally goes to the municipal dump where it's usually buried at the ratepayers' expense. In the vegetable gardener's case, there is no waste; we gardeners return any reject vegetable parts to the soil via the compost heap or worm farm. This is genuine environmental activism, not the virtue-signalling sort.

1 According to the US National Heart, Lung and Blood Institute.

A small number of readers of an early draft of this book took me to task for drawing a distinction between the environmentalism I advocate and activists in the green movement. I felt it important to distance myself from them for a number of reasons. First, bear in mind that I have been a staunch advocate for conservation for most of my life. In the 1970s I was one of many who were advocates of plantation forestry rather than logging of wilderness. We laid the groundwork for Prof Ian Lowe's "An Alternative Economic Strategy for Tasmania: A Report of Principles". One of my contributions in the 1980s when I was secretary of what was widely believed to be the greenest branch of the Australian Labor Party was a document proposing conversion of the Hydro workshops in Moonah to manufacture solar hot water systems locally rather than importing them. Widespread adoption of solar hot water systems was sufficient to eliminate the need for a small hydro-electric dam such as was being proposed at the time.

The use of aquaculture to conserve wild fish stocks, co-generation of energy, sustainable tourism and many other ideas were part of what we called a "greenprint" for the future. Unlike the greens of today, I remain very much in favour of the many proposals put forward at that time, rather than opposing them.

I am a practicing Stoic and very much have in mind Epictetus' advice: *"When you do anything from a clear judgment that it ought to be done, never shrink from being seen to do it, even though the world should misunderstand it; for if you are not acting rightly, shun the action itself; if you are, why fear those who wrongly censure you?"* I am not writing this book to make money, though I'm sure it will and if my words offend the politically correct: tough!

When you grow all, or nearly all, your own food you don't need to earn as much money. Deliberately restricting your earnings in this way means you don't need to pay as much income tax. For my 30th birthday in 1981 I was given John Seymour's "Complete Guide to Self-Sufficiency", a comprehensive how-to for living simply on the land. My future wife and I purchased our small farm eight months later, a profoundly political act inspired by Helen and Scott Nearing's book: *Living the Good Life*.[2]

When I began gardening I read everything I could on the topic and early on read FH Billington's *Farmers of Forty Centuries* from the local library. My interest in climate was piqued and I ended up studying this at university when in my fifties. I spent my early teenage years

2 Unlike the Nearings, we are not communists. Our politics is best described as middle of the road and I am also strongly libertarian. The Political Compass has me in the same region as the Dalai Lama. https://www.politicalcompass.org/

suffering from what was called at the time The Big Freeze in the UK before emigrating to Australia. In my late teens, the mid-century cooling and associated drought hit Biafra and Ethiopia with severe famine making a lasting impression on me of the importance of climate change.

Cooler might very well be better for us privileged whites, but not so desirable from the point of view of subsistence farmers in sub-Saharan Africa.

Stoicism

> *"Stoicism... offers a strong affirmative vision of what life is for: the pursuit of virtue. Living virtuously means living by reason, and the Stoics regard reason as calling for honesty, kindness, humility, and devotion to the greater good. It also calls for involvement in public affairs — that is, in the work of helping others in whatever ways are available. Instead of living to satisfy desires, Stoics regard themselves as meant to function as parts of a whole. There is great joy to be had in this, though it is not the variety that comes from the acquisition of things or approval from others. The happiness the Stoic seeks is eudaimoniad — the good life, or well-being. Virtues bring about that type of happiness as a byproduct, and Stoics regard this as the only reliable path by which happiness can be secured."*[3]

To the ancient Greeks, philosophy wasn't an arid academic subject, it was a way to live your life. Stoicism had its competitors the main one being Epicureanism. Stoicism claims that living justly and virtuously is the highest good that one can experience, and that pleasure and pain are to be treated indifferently. Epicureanism claims that we should seek to maximise our own pleasure and thus avoid pain. Both instructed us to live according to Nature where Nature is broadly defined as *the way things are*. Both are about thinking and acting rather than preaching and evangelising.

There is a problem with *the way things are*: humans are very good at disagreeing. More about that in the appendix on page 208.

> "Everything we hear is an opinion, not a fact. Everything we see is a perspective, not the truth."
>
> — Marcus Aurelius

3 Farnsworth, Ward. "The Practicing Stoic: A Philosophical User's Manual", David R. Godine 2018. Kindle Edition.

Preface

In 1992, my first book: *Complete Organic Gardening* was published to wide acclaim. There were some problems with this. It wasn't quite the book I had wanted to write, it was far from "complete" (no book ever can be), and my 50% share of the profits seemed a lot smaller than the 50% claimed by the publisher — closer to 5% in fact. So it goes... This book promises to be much closer to what I wanted to write, though that too has changed over the intervening years.

Like its predecessor, the content is information that I have found useful, but scattered through several books. Having it all in the one place is a great convenience. I also provide commentary on what I have found to be reliable information and what I have found to be less applicable. It is intended to be useful both to the beginner and the experienced gardener — the home gardener and small-scale market gardener.

It's a fact of the writer's life that the enjoyable part is everything that comes before writing down one's thoughts, the research stage. Some trains of thought compel one to write — it's almost as if the piece writes itself. The hard part is writing all the bits in between to knit everything together into a coherent whole. Hardest of all is the reading and rereading to eliminate as far as possible misunderstanding, and where possible simplify the language to ease understanding.

Mostly, I write about my personal experiences, rather than at second hand. Where I do write about others, it's generally because it relates to thoughts I have had, or am having. In a word, this book is intensely personal. It also tends to ramble because topics that seem quite unrelated to the specialist seem to me quite the opposite. This will either annoy the hell out of you, or you will find it entertaining and challenging, as have the regular readers of my Internet website.

Jonathan Sturm 2 December 2011

Introduction

In 1982 the local publican (Boney) offered me as much beer as I cared to drink while he ate a nine-litre (two gallon) bucket of my fresh unpodded garden peas. Now Boney was a *connoisseur* of peas. He pointed out that not only were they the finest peas he had ever tasted, the pods were all full, with every pea full size. And to top all of that, there were he said an extra two peas in every pod!

Consumed with curiosity, I visited the next-door neighbour's garden, some 50 metres (55 yards) from mine. The neighbour and his farm workers were harvesting peas. While chatting with them, I grabbed a few pods and ate the peas. Sure enough, Boney was right. My neighbour's peas were bland when compared to mine. They were starchier and less sweet. I enquired as to the variety; they were Greenfeast, the same as I was growing. I then asked where the pea seed had been bought — the same store. Finally came the crucial question: what had they been manured with?

The reply was 8:4:10 — orchard fertiliser. The peas Boney liked so much had been grown with cow manure!

In four decades of farming and gardening, the only material I have used not permitted under the official organic guidelines is the herbicide, glyphosate. The reason for growing organically has nothing to do with fear of chemicals on my part. Rather, it was initially poverty, and later because organics was working so much better than conventional.

There is a common myth that organic production levels are necessarily much lower than when using artificial fertilisers, and that organic fertilisers are more expensive. My experience and that of many other growers frequently do not support these assertions. If the first claim be true, then it's a mystery why for example the world record tomato grower according to the Guinness Book of Records grows organically. When the writer was market gardening, the cheapest nitrogen source was that in chicken deep-litter. The cheapest artificial source, sulphate of ammonia, wasn't even close. Needless to say, chicken deep-litter contains many more nutrients than nitrogen.

It is important to realise that the two growing systems, organic and conventional, are 95% the same. Most of the remaining 5% of differences are in the grower's attitude toward the soil. Organics is not merely the substitution of a natural material where a synthetic material is

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I like the physical activity of gardening. It's kind of thrilling. I do a lot of weeding.

—John Hurt

usually used. Plants are able to use several methods of obtaining their nutritional needs. One is to obtain them from water-soluble minerals (usually chemically processed commercial fertiliser).[1] Another is to obtain them from "insoluble" minerals when soil microbes and earthworms render the nutrients available to plants. The minerals are usually already there, in the form of silt, or may have been placed there as crushed rocks by the gardener, or farmer. Yet another source of plant nutrients is the decaying remains of plants, and/or animal manure.

It is worth pointing out that it is not only organic proponents who believe avoiding excessive amounts of water-soluble mineral fertilisers is superior. Water-soluble fertilisers generally lead to increased pest and disease problems requiring ever more potent biocides for their control, along with increased soil erosion as soil organic matter declines. Reducing their use, or avoiding them altogether, increases the plants' natural resistance to pests and disease. Eliminating or reducing water-soluble fertiliser only works in soil with an abundance of organic matter and living organisms. Such a soil is easier to till, drains better, holds more moisture and is less prone to erosion.

It's also interesting to note that in several farm trials using organic fertilisers alongside conventional artificials at half the usual rate produced results far ahead of using the usual rates of artificials alone. The benefits weren't just increased yields, but there was also a marked reduction in fungal and viral disease, and substantial increase in the quality of the produce.

As a consequence, many Tasmanian farmers and horticulturists have adopted organic techniques without necessarily converting to fully organic. I played a minor role in this and have considerable admiration for those who were adventurous enough to engage in the type of research we commenced almost forty years ago.

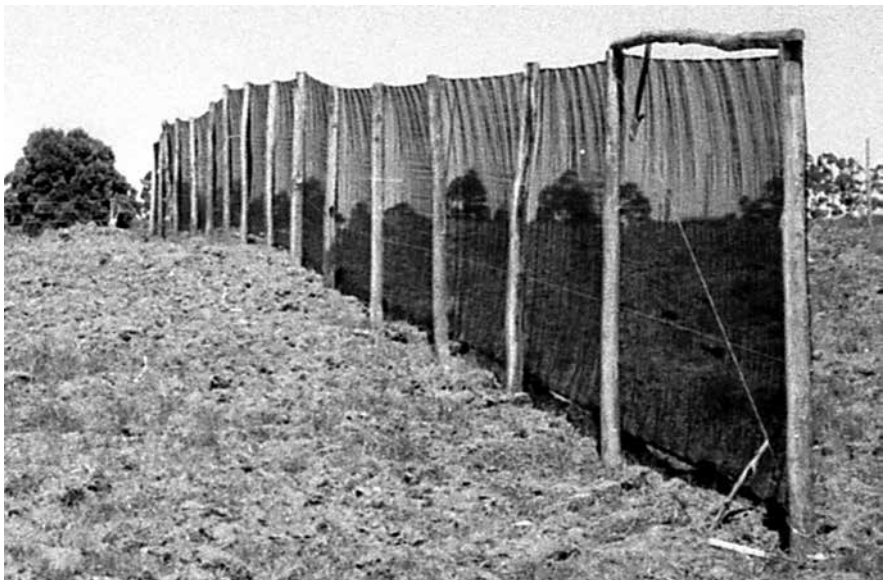
The apple and pear growers had set themselves the goal of reducing biocide inputs by 95% in ten years. When they reached their goal in five, I was jubilant. I saw it as a very large step in the right direction. The biggest hurdle, control of the fungal disease black spot (aka apple scab), succumbed to two organically acceptable materials: builders' lime (calcium hydroxide) and waterglass (sodium silicate). Dr James Wong of the Department of Agriculture discovered the former and I the latter solution. James' proposal was the cheaper and certainly the safest.

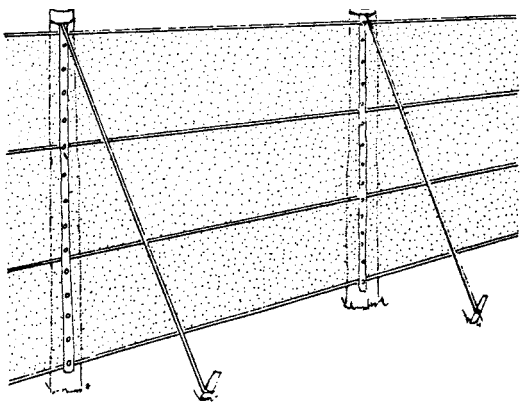
One of the purposes of this book is to provide sufficient practical information to be a successful gardener, organic or otherwise. While

1 Though not always. Raw animal manures contain water-soluble nitrogen that only becomes stabilised by composting.

the commercial organic producer is necessarily restricted to materials and technologies defined in an organic standard such as that maintained by the National Standard for Organic and Bio-Dynamic Products, no such restriction applies to the conventional grower or backyard gardener who is free to adopt whatever he or she deems appropriate.

To be a successful small-scale market gardener requires not just hard manual labour, but also a sound grasp of management principles, economics, marketing, organisation, decision-making and biology. You also need enthusiasm, self-discipline and a high level of motivation. For a decade my wife and I were market gardeners, so I touch on these topics at various points throughout the book.





Gardens need protection from the wind. Two metres (6 foot) tall 50% shadecloth works well, but doesn't harbour predators. We used discarded lengths of black dripper line and galvanised clouts to pin the cloth to the posts. The wire stays were essential in our windy environment!

Your Garden

"Advice… advice… advice… Some of it suggests one thing and some of it says just the opposite. Most of all it is very good advice… for someone. But not all of it turns out to be good advice for you.

Why is that? It is simply because your garden and your gardening style are unique. You can't expect your work glove to fit perfectly on someone else's green thumb."

—Lois Levitan, *Improving Your Gardening with Backyard Research*, Rodale Press 1980.

Choosing the Land

Many people approach me for advice after they have purchased their land. All too often, it is not very well suited to what they want to do. However, all except the very worst sites can be improved to the point of being productive.[1]

The best soils for gardening are loams, light soils are second best and heavy soils worst though this needs some qualification. Loam is balanced soil—a mixture of sand, silt and clay. Light soils are predominantly sand making them hungry and drought-prone, but they produce crops earlier than the other two soil types, and may be worked even when wet. Heavy soils consist of mainly silt and/or clay so they tend to be very fertile, but they warm slowly in the spring, and should *never* be tilled when wet.[2] Our soil is very heavy and a friend's market garden referred to often throughout this book started out as almost pure white sand.

Vegetable gardens need shelter from strong wind. If this shelter does not already exist, then windbreaks will need to be established before you can commence gardening. Artificial windbreaks can be made, but they are rather more expensive than natural ones. As well, they do not harbour predators like a well-designed windbreak of trees and shrubs. A windbreak reduces the wind close to the ground for a distance on the leeward side equivalent to around 25 times its height. It's important to keep artificial windbreaks no higher than a couple of metres. Any taller and they have a tendency to fall over.

The aspect of the land is very important. The soil needs as much

1 John Jeavons started his garden in California on clay that was pH 8. If I recall correctly it had been a car park.

2 Tilling wet clays creates large, rock-like clods. Tilled when too dry, they turn to dust. Locally, our heavy soils are referred to as "Sunday soil"; there's one Sunday in the year when their moisture content is just right.

sun as you can provide and a north-easterly slope will warm quickest. In warmer districts, a north-westerly slope that warms slower might be better. Note that these recommendations are for the Southern Hemisphere.

Rainfall is another important consideration. The worst situation is too much rain. It leaches nutrients, and causes erosion and fungal disease problems. While a dry situation can be ameliorated by irrigation, the dissolved salts in groundwater can accumulate to excess in many soils, eventually poisoning them. The best situation is one of moderate rainfall with adequate supplies of water of reasonable quality to supplement the rain.

Land that is too level will create drainage problems and allows cold air to accumulate. Land that is too sloping will cause erosion unless terraces are created. Terracing is expensive and the extra effort required moving produce and compost up and down the slope consumes a great deal of energy. Land of moderate slope allows good drainage of water, and in frosty districts, cold air.

For market gardening, you will need easy access to the road and sheds. As well, you will need ready access to a market for your produce. Most important of all, you will need a source of inexpensive (that is locally sourced) compost ingredients.

When my wife-to-be and I were looking for our land, we only knew that we wanted to be within reasonable commuting distance

Gardening in raised beds makes for excellent drainage and the permanent footpaths make for comfort especially in wintertime.

of our state's capital city, the soil had to be a sandy loam and rainfall around 800 mm (32"). In the event, we discovered that good land was very hard to find. Farmers are nowhere near as stupid as city-dwellers would like to believe; they prefer to subdivide their least productive land for sale to hobby farmers. We ended up with heavy soil, rather than sand, or loam. The property is gently sloping, so it drains well (for heavy soil) and there are no frost pockets. Our water source for irrigation is at the top of the slope, so we can use gravity for irrigation, rather than expensive and unreliable pumps. Unfortunately it is a runoff dam, not on a permanent water course, or spring. One winter it failed to fill. And the following summer, we emptied it six weeks before the first autumn rains.

One potential problem for us as organic producers was spray drift from our neighbour's property. When we first moved in, we were surrounded by cattle pasture. Some two years later, our neighbour established an apple orchard on the windward side. The first time the tractor driver sprayed the young trees, I approached him and thanked him for spraying when the wind blew the spray away from our property. Ever since, he has always taken our needs into account.

A few years later, I received a telephone call from a newcomer to the district. She wanted to know what the organic sprays for apples were. I told her that organic apple production was far more than merely substituting organically acceptable sprays for those used by conventional growers. My remark appeared to upset the caller; she told me that all she wanted was what she had asked for so she could tell her neighbour what to use. I asked her who her neighbour was. When she told me, I informed her that he was using organically acceptable sprays; he was in fact already an organic farmer. "Oh, but he sprays all the time," she said, huffily, and hung up.

Basics

There is a bewildering number of methods of growing vegetables. Many books have been written extolling the virtues of no-dig, mulch, raised beds, circle gardens and many more. This book draws on selected aspects of many different ideas. The systems the writer advocates are based on the concept that if you are to make a profit from growing vegetables, then time management is of the essence. Even if your "profit" is "only" money saved on shop-bought produce, the same basic principles still hold. There is no single way for every gardener everywhere that's best as so many writers imply.

As an example, let's take carrots. On average, my organic fertiliser costs have been a mere 2.5% of the gross return for all crops combined, so the critical profit factors are the time consumed and yield per man-hour. Typically, 50%, or somewhat less of the time to produce a crop is spent actually growing it and 50%, or somewhat more, is spent harvesting and marketing.

There are three basic methods of growing carrots. The first is growing them in single rows spaced 30 cm (12") apart with 75 mm (3") between plants. This is the conventional method you will find in most books on vegetable gardening. It has several disadvantages. The wide row spacing is to allow the gardener room to hoe, weed and harvest the crop. The continual foot traffic between the rows compacts the soil, reducing water and air infiltration and consequently, yields. The method works particularly poorly in shallow topsoil—most varieties of carrots prefer deep soil. Heavy rains can wash the soil badly, leading to incomplete rows, and consequent topsoil and nutrient loss.

The main root mass is not the stout taproot that we consume; rather it's an almost invisible network of fine roots and root hairs that exploit uncompacted soil to obtain water, nutrients and oxygen. The compacted soil of a footpath is inimical to this. Only certain plants find tight soil a place worth growing in: typically docks, wireweed, plantain etc whose role in the ecology is to break up such compacted soil.

The second method is to grow the carrots on raised beds, 1.2 m (4') or so wide and 10–15 cm (4–6") high with 40–50 cm (16–20") wide permanent footpaths (or tractor wheel-ruts) between. The carrots are sown in rows along its length, the plants 7.5 cm (3") apart with the rows 15 cm (6") apart. The yield per unit area is higher than with the first method, because the soil that the carrots are growing in is never compacted by being walked on, and consequently water and air infiltration is unimpeded. Topsoil depth is also greater, allowing more soil for nutrient exploitation by the plants' roots. Yields are generally 50–100 % higher per unit area than with the first method.

The third method, that advocated by John Jeavons in his excellent book *How to Grow More Vegetables* (10 Speed Press), is to sow the carrots 7.5 cm (3") apart each way across the raised beds as used in method two. This has all the advantages of method two, but two disadvantages. The first of these is related to sowing. It is difficult, though not

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Gardens are not made by singing "Oh, how beautiful," and sitting in the shade.

—Rudyard Kipling

impossible, to sow seeds in drills 7.5 cm (3") apart. Jeavons advocates broadcasting, or sowing individual seeds on 7.5 cm centres. Broadcasting is quick, but it's very difficult to ensure the seeds are evenly covered with soil so that they germinate simultaneously, most important in close planting. If germination is staggered, the earliest plants to germinate will shade out the later germinating plants.[3] Thinning a broadcast crop is very slow. Sowing on 7.5 cm (3") centres is also slow, but means that minimal thinning is required.

The second disadvantage is that weeding cannot be done with a conventional hoe; it must be with fingers, or a custom short-handled narrow hoe. It should be pointed out that in moderately weed-free ground, that only very few finger-weedings are required as the plants quickly close up the space between, and the leaves suppress the light reaching any late germinating weed seeds. The yield from Jeavons' method is as much as 50% greater than Method Two.

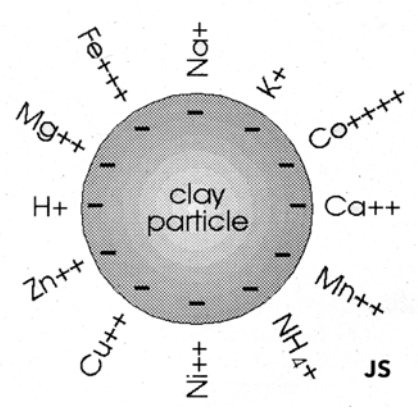
While it is usually believed that Method One is the most time efficient, Method Two yields are far enough ahead in yield that it becomes difficult to justify the extra area Method One requires. Just as with Method One, the rows are readily sown with a mechanical seeding machine, and a narrow hoe is used to remove most weeds very quickly. We estimate that Method Two consumes less than 50% of the time per kilogram of carrot produced when compared to Methods One and Three.

Gardeners who like to use mulch on crops such as carrots that require a constant level of moisture will have noted that Jeavons' method is not adaptable to mulching. Jeavons' mentor, Alan Chadwick points out that the leaves of the crop plants rapidly grow to shade the soil, forming what he called "a living mulch". Method Two above, like Method One, is more conducive to mulching after seedling establishment, but also creates a living mulch as in Jeavons' Method Three, albeit somewhat more slowly.

Raised-bed gardening actually pre-dates row-gardening. Row-gardening was developed following the publication of Jethro Tull's *Horse Hoeing Husbandry* in the seventeenth century. The Tullian row cultivation method was developed for grain production, quickly supplanting the broadcast method in most British farming districts though broadcasting remained in use by poorer farmers until the late nineteenth century. Weeds that previously needed to be pulled by hand were quickly controlled by either horse, or human powered hoes. What we have done is adapt what seems the best of both

3 This is particularly undesirable in commercial production where evenness of carrot size is important.

systems. In conventional row cultivation, 50% of tillage is required to undo the damage caused by soil compaction.[4] If you don't compact the soil in the first place, you've reduced tillage by half. The advantage of row-cultivation, speed of hoeing for weed control, is retained.



What I attempt to illustrate here is that you are not stuck with any single method. You are free to come up with your own adaptations that suit *your* needs, situation, climate and other circumstances.

Soil

Soil consists of a mineral fraction, water, air and organic matter. The ideal soil for growing crops is said to be 50% solids, 25% air, and 25% water after all excess water has drained away. The soil is then said to be at field capacity. The organic matter needs to be 5% or more of the total solids for it to be suitable for organic production. The mineral portion is subdivided into silt, sand and clay. The organic material can be subdivided into living and dead, or raw and humified.[5]

The relative proportion of the three mineral solids determines the *workability* of the soil. Silt and clay particles are very tiny. Where they predominate over sand, the soil is said to be heavy. It contains little air and holds onto a lot of water because of the huge surface area of the tiny soil particles. Tillage tends to be rather difficult because the soil is very stiff. Where coarse sand particles predominate, the soil is said to be light because it's loose and easy to till. There is an abundance of air, but little water holding capacity. The best soils from the point of view of the vegetable grower have a balanced proportion of all three mineral types and are classified as loams. However, even the most unpromising soils can be improved to the point of economic productivity. I will discuss two market gardens closely in this book. Our soil is silty clay and that of our good friends, Ian and Caryl Cairns, started out as almost pure white sand.

4 In an ABC Country Hour broadcast many years ago I heard of a British farm trial of tram-tracking, where the tractors tyres occupy permanent wheel ruts. The growing area between them is never compacted and the trials showed you could either double the area tilled per hour, or halve the tractor horsepower.

5 Humified means decomposed to form humus.

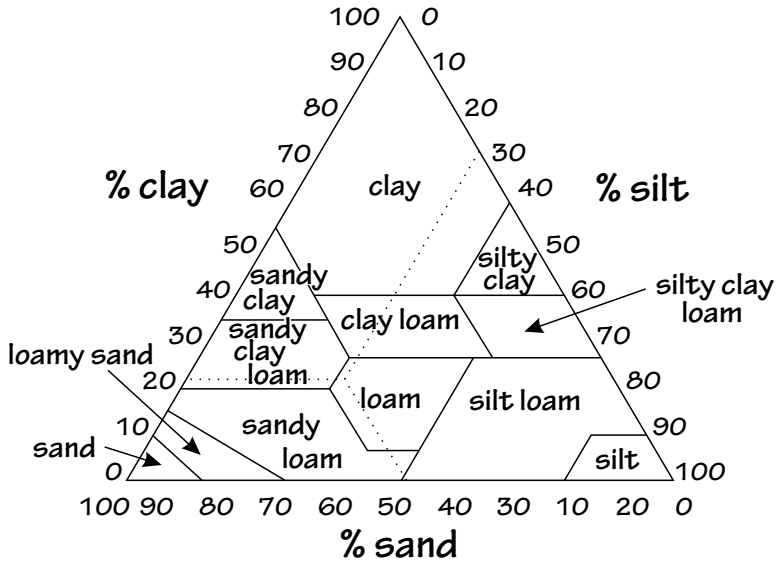
Clay particles are rounded, as well as very small. They pack together very tightly, and make the soil feel sticky. Clay particles carry a negative electrical charge, so they attract positively charged elements and compounds such as the essential crop nutrients: calcium, magnesium, potassium, ammonium, molybdenum and sodium. These positively charged materials are called cations (pronounced Cat-Eye-Ons). The amount of these elements a soil can contain is called its Cation Exchange Capacity (CEC) and this is an excellent measure of its potential fertility, an important aspect of capacity to produce. Cations held by the negative electrical charges on the clay particles cannot be easily leached from the soil by rainfall, or irrigation. Plants' root hairs emit positively charged hydrogen ions that displace the cations, rendering them available to be absorbed by the plant on an as needed basis.

Silt particles, while similar in size to clay particles, are flattened rather than rounded. Like clay particles, they also pack together very tightly, but make the dry soil feel silky when rubbed between the fingers as the flat plates readily move against each other. Unlike most clays, silts contain a variety of nutrients that are made available to plants through biological activity. Silt is formed by weathering, particularly the abrasive action of glaciers on rock and the bulk of silt on the planet was formed during the glacial phase of the current and previous ice ages.[6] Australia's soils are some of the oldest in the world and therefore contain less of these plant nutrients. In any event, it is rare that silt contains an ideal balance of nutrients; nutrient supplements are nearly always called for.

Sand particles are large so sand has big gaps between them when it is packed. They make the soil feel gritty when rubbed between the fingers. While sands contain negligible amounts of plant nutrients, and lack clay's ability to hold onto them, they improve the soil's drainage, air holding capacity and make it much easier to till.

Organic matter falls into two categories, living and dead. The dead material is a source of plant nutrients as it decomposes. Bacteria are able to convert raw organic matter into a material called humus. Humus acts as a sponge for water, so it improves the water holding capacity of sandy soils. By holding silt and clay particles apart, it improves the drainage and aeration of heavy soils. Heavy soils with adequate (5–10%) humus also become much easier to till. Like clay, humus also carries negative electrical charges so it increases the soil's

6 We are in the Holocene interglacial epoch of an ice age called the Quaternary that began 2.58 million years ago. Prior to that Earth had no ice caps at the poles. Earth has experienced at least five ice ages.



The diagram above is the USDA Soil Triangle. The dotted lines intersecting in the area labelled loam show that's for a soil consisting of 50% sand, 20% clay and 30% silt. On a small scale you can amend a soil based on using the triangle. First, you need to know the percentages of sand, silt and clay in your soil.

Gather several cupfuls of topsoil from your garden and mix thoroughly together. The idea is that they be a representative sample so take each cup from a separate location. The soil then needs to be air dried before using a kitchen sieve to remove gravel, stones, slaters etc. Take one cup (250 ml) of the remaining "fine earth" and put it into a straight-sided jar such as a canning jar with three cups of water into which you have dissolved a tablespoon of sodium hexametaphosphate.* Shake the concoction well to disperse the soil, then take a metric (mm) ruler and measure the depth of soil as it settles out. At 40 seconds you have the sand measurement, at 30 minutes the silt measurement and after 12 hours the clay measurement. Sand depth ÷ total depth × 100 = %sand. Silt depth ÷ total depth × 100 = %silt. Clay depth ÷ total depth × 100 = %clay.

The writer's soil was 50% silt and 50% clay. When he reverted to having a mere 500 square metres (600 square yards) of garden it became feasible to add sufficient sand to make the soil a clay loam rather than silty clay. It certainly made harvesting carrots *easier*!

* Water softener such as Calgon. Other water softeners such as trisodium phosphate (TSP) or sodium carbonate (washing soda) are not suitable. They don't disperse the soil particles before precipitating them.

(CEC). Increasing the humus level of a soil is often the only economically realistic way to improve the CEC, and consequent increase in yield potential. If marl, a mixture of clay, silt and carbonate rock is available, that will increase CEC, but not provide the many other benefits of humus.

Fungi and yeasts can also decompose organic matter. This process tends to produce alcohols and other growth inhibitors, rather than humus. One of the key differences between organic and mainstream cropping is that the organic grower endeavours to promote humification in the soil, consciously, or otherwise. Conventional growers in the past were trained to ignore soil biological processes as relatively unimportant. The best known example of humification is the process of composting. This is a major topic and so has its own chapter later in the book.

The living components of the soil include fungi, bacteria, actinomycetes, insects, plant roots, earthworms, nematodes, algae, viruses and protozoa. OK, I know that viruses aren't classified as being truly alive, but they do qualify as an intrinsic part of the living system. There is no living system that is free of virus particles, and there were new candidates for living organisms as this book was first being written: nano-bacteria. Fertile soil supports at least as much living matter within it as we can see above the soil surface. The sheer number and variety of these organisms is mind-boggling. A teaspoonful of living soil contains *billions* of microbes, most varieties of them remaining unknown to and undescribed by science. In organic production, the dynamic balance between them is the primary concern. Fortunately, we do not need to know very much about the many complex interactions — after millions of years of evolution, they are very good at managing these things for themselves. A few simple principles mastered by peasant farmers throughout the world are all that is required.

While conventional agriculture has been obsessed with the most obvious parts of the plant, the above ground parts, these are fed by a complex underground root system. The roots take up the mineral nutrients, nitrogen, phosphorus, potassium, sodium, calcium, magnesium, trace elements and water that the leaves require to convert carbon dioxide from the air into sugars, starches and other carbohydrates. The roots have short protrusions called root hairs that are

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The only way to get positive feelings about yourself is to take positive actions. Man does not live as he thinks, he thinks as he lives.

—Rev Vaughan Quinn

responsible for nutrient uptake. Their health requires adequate moisture and air, hence the earlier prescription for healthy soil being 50% solids, 25% air and 25% water. Too much water and too little air is a common cause of ill-thrift in plants.

Many plants have fungi that live partly in the soil and partly in the root exchanging phosphorus from the soil for carbohydrate from the plant. They are called *mycorrhizae* and some plants cannot survive without their particular species of *mycorrhiza*. Many others exhibit poor productivity without them. Another example of symbiosis is that between the nitrogen-fixing bacteria called *rhizobium* and legumes. *Rhizobia* live in nodules on the roots of the *leguminosae* plant species. They convert nitrogen from the atmosphere that plants cannot use directly, into protein. The legumes include clover, Lucerne (alfalfa), beans and peas.

It was recently discovered that mycorrhizae play an important role in tomato plants' resistance to pestilence. When the plant's leaves are attacked, this generates a chemical signal that the mycorrhizae detect. The mycorrhizae then send a chemical signal to the plant to begin generating chemicals that are toxic to the insects munching on the plant's leaves. They also send a chemical signal to the mycorrhizae living on nearby tomato plants to do the same.

The single most important soil organism is the earthworm. The health and vigour of this muscular tube of protoplasm is the best indicator of overall soil health. If there are no earthworms, then plant productivity is but a small fraction of its potential. There are three main types of earthworm: the compost worm, the earthworker worm and the root-dwelling worm.[7] Compost worms require copious quantities of protein-rich organic matter and do not ingest soil. Earthworker worms require much less organic matter and ingest soil. The worms sold by worm farmers are compost worms, and are less important from the standpoint of the gardener than the earthworker worm. The root-dwelling worms include the huge Australian *Megascolides australis* that average a metre in length, but can grow to three.

The gut of earthworker worms transforms the minerals in the silt particles they ingest into usable plant food. As well their excreta, called worm-casts, are small crumbs that are just double the diameter of the length of a root hair. These crumbs are essential to the open structure of fertile soil and are easily damaged by excessive tillage. In point of fact, earthworms perform much of the tillage in organically managed soil. This concept taken to its extreme has led

7 Compost worms are usually tiger worms (stripy) or red wrigglers. Both exhibit considerable activity when handled while pasture worms are more sluggish.

to what is called no-dig gardening. While this is an option for the home gardener, it is generally too unproductive and costly for the commercial producer.

Even though the compost worm is relatively unimportant in the soil, it comes into its own when used for converting bulky organic matter into a rather special compost called vermicompost. This is discussed further in the chapter devoted to composting.

Plant Nutrition

While conventional growers feed the *crop*, the organic grower feeds the *soil* and the many micro- and macro-organisms living in it. These organisms then provide the crop's nutritional needs. The reasoning behind the first approach is that artificial fertilisers are said to be much cheaper than organic fertilisers. This is only superficially true. The reasoning behind the organic approach is that organic fertilisers produce healthy crops that need little if any expensive pesticide or fungicide materials usually considered essential by conventional growers. Many of the nutrients the crop needs are met by decomposition of the silt particles in the soil and they come with the land you are farming or gardening at no extra cost.

Most vegetables and fruits grown organically are tastier than their conventional counterparts; they also survive storage longer. Most consumers believe that organically grown is better for your health. Frankly, that's almost irrelevant for this organic gardener; I like the greatly enhanced flavours so there's no competition when I have a choice.[8]

The health of the living fraction of the soil is dependent on an adequate level of humus, optimally between 5 and 10%, a constant source of fresh carbohydrate and lignin (dead plant material), a much smaller constant supply of protein (such as that in animal manure and legumes), and mineral nutrients at adequate levels and in the appropriate ratio. The most important nutrients are the anions nitrogen and phosphorus, and the cations calcium, magnesium, potassium and sodium. Also of importance are the nutrients needed in only small amounts, the trace elements.

The crop nutrient in shortest supply for the plants' needs is referred to as a crop-limiting factor.

8 The difference in flavour between organically grown and conventional is most marked in meat. Organically raised livestock are notably healthier than their conventionally raised counterparts, hence the extrapolation to humans. There is nothing quite as dramatic as the difference in flavour of organic pork, chicken or beef.

The relative amounts of nutrients are also important from the point of view of availability. An excess of one element can inhibit, or enhance the availability of another. This is shown diagrammatically below.

Major Elements

Carbon, hydrogen and oxygen

Somewhat surprisingly, you won't usually see these elements listed as crop nutrients in many books on gardening. It's surprising to me because the greatest bulk of a plant consists of these three elements. Carbon in the form of carbon dioxide (CO_2) plus hydrogen and oxygen in the form of water (H_2O) are converted by the chlorophyll in chloroplasts in green plant tissue to carbohydrates. The simpler carbohydrates are called sugars, more complex carbohydrates starches, and the most complex of the lot, cellulose. Cellulose accounts for the great bulk of plant tissue as it is the major component of plant cell walls.

While carbon dioxide levels are usually not perceived as a crop-limiting factor, greenhouse growers gain substantial increases in yields by increasing the amount of carbon dioxide available to crops. While the average background level is approximately 400 ppm, they raise the level to between 1–2,000 ppm. The elevated level of CO_2 means the pores in the plants' leaves do not need to open so wide, greatly reducing the amount of water the plants transpire. Doubling the level of CO_2 reduces a crop's water need by approximately 25%. At 1–2,000 ppm, yields of cucumbers and tomatoes are 50% higher.

In India, garden beds are surrounded by a wall of greenhouse polythene. This reduces the tendency of locally generated CO_2 to blow or drift away and results in increased crop yields. When Bill Mollison and David Holmgren were developing their Permaculture system, Bill and I discussed this while eating Vogel bread sandwiches in Salamanca Place on the Hobart waterfront. We figured that keeping chickens, or making compost in the greenhouse would provide a useful source of not only warmth in the colder months, but also CO_2 during the colder weather when keeping the greenhouse vents closed results in air being depleted of this essential nutrient.

Water is the single greatest crop-limiting factor, but not because of its nutrient content. Rather, water is the transport system for nutrients and hormones, the latter being chemical messengers that regulate the growth of all living tissue. Water is so important it is dealt with separately as a major topic.

We are what we repeatedly do. Excellence, then, is not an act, but a habit.
—Aristotle

Phosphorus

Phosphorus encourages root development and is essential for the formation of protein in the plant. As well, it increases palatability of the plants since it promotes the formation of fats and convertible starches. By stimulating rapid cell development, phosphorus increases the plants' resistance to disease. Many plants respond to a phosphorus deficiency by showing a reddish or purple colour in their leaves. The common weed fat hen is an excellent indicator plant for this condition.[9] Heavy feeders are stunted when phosphorus is in short supply. Phosphorus toxicity symptoms include the margins and interveinal areas of older leaves dying. Younger leaves show interveinal chlorosis, particularly tomatoes, celery and sweet corn. Since this latter condition is usually caused by excessive use of superphosphate, or other water-soluble phosphorus materials the organic grower is unlikely to see it.

The most popular fertiliser source of phosphorus in recent decades has been superphosphate. The response of crops to super has declined over time, more and more being necessary to maintain satisfactory yields. On average, only 30% of the phosphorus in super becomes available to plants in the season of application. While a minute fraction leaches out of the soil through irrigation and rainfall, the bulk is locked up in the soil through chemical reaction with iron. Phosphorus from farmland appearing in rivers and streams is generally carried there through erosion of the soil, rather than phosphorus in water solution. Humic and fulvic acids, earthworms and associated beneficial bacteria and fungi in a fertile soil gradually "unlock" the phosphorus in reactive phosphate rock, superphosphate residues and silt, making it available to plants.

The fertiliser recommendations followed by most farmers results in the application of considerably more phosphorus than is removed by the crops. Consequently, many farms have built up phosphorus reserves in their soils that are sufficient for decades, and in some cases centuries, of cropping. Where low soil phosphorus levels are determined to be a genuine problem, reactive phosphate rock (RPR) is the organic alternative to super. RPR is cheaper (or should be) than superphosphate as well as containing a higher percentage of phosphorus and trace elements. Under typical soil conditions, the phosphorus in RPR is only readily available when the soil pH is around 4.5 to 5.5, somewhat lower than 6.0 to 6.5 that is optimal for most

9 One variety of fat hen called Good King Henry has a naturally purple tinge to its leaves, but they are apparently much larger than the ordinary sort.

crops. However, the organic acids associated with bacterial activity in a fertile soil appear to be capable of unlocking the phosphorus when the soil pH is a more acceptable 6.0-6.5.

Many, if not most Australian organic producers are exploiting the phosphorus residues locked up from their predecessors' superphosphate applications. The questions then arise: How long will those reserves last? Is there sufficient phosphorus in these residues and the silt fraction of the soil for economic, long-term production? For conventional farmers, several questions arise:

- Does it make economic sense to leave 70% of the phosphorus in superphosphate unused?
- How can farmers exploit the phosphorus reserves they have built up over many decades?
- How long will the world's fossil phosphate deposits last?

We do not have satisfactory answers to these questions at this time. Nevertheless, it should be apparent that fossil phosphate reserves will continue to dwindle, inevitably driving the price higher. As well, it would appear to be sensible to optimise the availability of any applied phosphate, rather than allowing the bulk to become chemically locked up to the detriment of the soil biology and the farmers' input costs.

Nitrogen

Nitrogen stimulates the production of plant tissue and influences the protein content. Nitrogen applied as nitrate produces a blue-green colour in plant leaves. When applied as protein, the colour is noticeably a more golden-green. Excessive nitrate levels are associated with increased fungal disease, delayed maturity of plants and weakening of plant tissue leading to lodging.[10] As well, nitrates in the plant sap are reduced by bacteria to nitrite that in turn is converted to nitrosamine, which is toxic to the consumer of the plant, animal, or man, particularly juveniles. Nitrogen deficiency symptoms in crops include the edges of leaves turning brown, smaller leaves and yellow-green foliage. Nitrogen toxicity symptoms include rotting of roots and delayed maturity. Young leaves are dark green and older leaves yellow with necrotic spots.

Nitrogen can be supplied as protein (rotted animal manure, legume green manure, fish, blood 'n' bone etc), or as water-soluble artificial fertiliser (Nitram, urea, ammonium sulphate etc.). It is worth noting that most raw animal manure contains much of its nitrogen as water-soluble chemicals such as ammonium carbonate. Raw animal manure is, from the point of view of the plant, very similar

10 Lodging is the condition where the plant stem is so weak, the plant falls over.

to artificial fertiliser in its effects, so well-rotted, or composted manure is much preferred. While a pasture can supply its own nitrogen needs through fixation of atmospheric nitrogen by clover, horticultural crops have a much higher requirement. Crops take up as little as 10% of applied water-soluble nitrogenous fertilisers. The remainder leaches into groundwater and streams to the detriment of the many organisms living there. While this may please the fertiliser manufacturers, it is not so great from the point of view of the farmer. As well as wasting money, the adverse impacts of leached nitrogen on the environment can lead to stiff penalties.

As protein slowly decomposes, it supplies the plants with nitrogen at the rate generally needed by the crop. Leaching becomes a non-issue. Where short-term nitrogen needs are not being met by the soil, liquid manures made from fish, comfrey leaves, or nettles are popular. Lucerne chaff tilled into the topsoil also works well, with the added advantage of containing plant growth hormones. This is particularly useful in the spring when the soil is beginning to warm up after winter dormancy.

In several field cropping experiments we applied pelletised poultry manure at a rate calculated to supply 50% of the usual artificial nitrogen application. This rule of thumb has worked well in supplying the nitrogen needs of most crops. One commercial grower applied a soil drench of 60 litres per hectare of Vitec liquid fish to a crop of broccoli. The plants responded as well as they did to artificials, even though the nitrogen content of the fish emulsion was a mere 2.8%. The artificial fertiliser salesman said to the grower: "You'd have been better off pissing on the crop than using this fish oil!" The grower responded: "Maybe that's what I'll do for the next crop!" The farmer told me it was easily the best quality broccoli crop he'd ever grown and it had been gratefully received in the Asian market.

Potassium

Potassium is essential for starch formation in the plant and the development of chlorophyll. Unlike phosphorus and nitrogen, which are part of the structure of the plant, potassium is more of a catalyst involved in plant processes. Deficiency symptoms include lowered resistance to disease, low yields and mottled, speckled, or curly leaves, especially older leaves. Potassium toxicity symptoms include marginal necrosis on the oldest leaves and in celery, black-heart.

How wonderful it is that nobody need wait a single moment before starting to improve the world.

—Anne Frank

More and more growers are coming to appreciate the ability of deep rooting plants to bring potassium from deep in the subsoil to supply their crops' potassium needs. Such plants are called biological ploughs, because they serve much the same purpose as a ripper, leaving deep channels in the soil when they decompose. In pasture, New Zealand graziers use chicory varieties developed for this purpose. In China, vegetable growers use Paulownia trees, whose large succulent leaves decompose to humus when they fall in autumn. The roots of Lucerne (alfalfa) and comfrey are capable of diving two metres and more into the soil.

Potassium is used to excess in many crop fertiliser programs. For instance, the recommended application rate on potatoes is twice the amount removed from the soil. This leads to reduced availability of calcium and many trace elements. As well, the most commonly used potassic fertiliser is potassium chloride (muriate of potash). This material is deadly to earthworms, since the mineral particles burn holes in their skin. Frogs, Nature's vastly underrated pest controllers, are also devastated by its use. Continual overuse of potassium chloride can lead to toxic levels of chloride and a consequent decrease in yields. Potassium sulphate (sulphate of potash) is a much better source of potassium in this regard, particularly as it includes sulphur, which is often in short supply in Australian soils. It is unfortunate that it is much more expensive than muriate. Overseas books recommend greensand and other sources of potassium not generally available to organic growers in Australia. Wood ash is also often quoted as a good source of potassium. However, it is only the twigs that supply significant amounts potash — tree trunks are not overly endowed with this mineral. They consist of mostly lignin and cellulose.

When the I commenced organic market gardening over 30 years ago, a soil test showed a deficiency of potassium. This was "corrected" with the recommended amount of muriate[11] of potash. In the following ten years, only compost was applied, and this is regarded as only a fair source of potassium. Nevertheless, a soil test showed that the potassium level had risen to become slightly excessive. Two decades further on, potassium levels have fallen to the point where a small amount, applied as sulphate this time round is proving beneficial for crops needing especially high levels of this nutrient.

Short-term potassium deficiency can be met with liquid manure made from plants that concentrate potash, such as Lucerne, comfrey

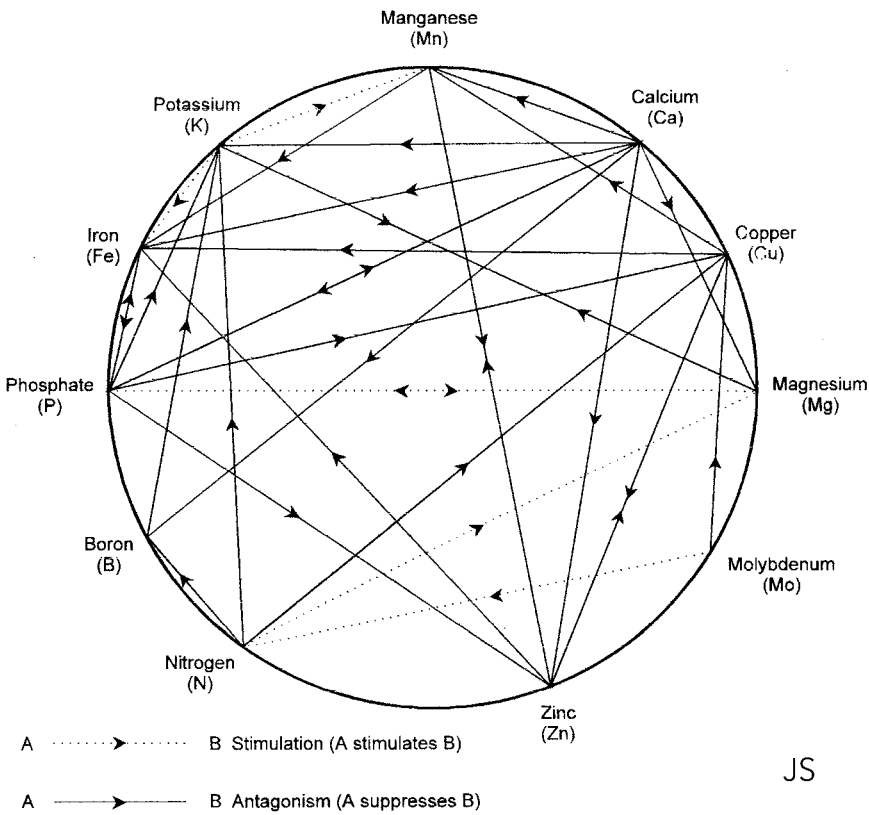
11 Yes, this conflicts with what was written above. I have learned many lessons over the years and sometimes you need to go in the wrong direction to learn which is the right direction.

leaves, or bracken fern.

Seaweed is often recommended as a good potassium source. Because seaweed contains potent plant growth hormones and auxins, large amounts can temporarily reduce plant growth. This means when seaweed is used for this purpose, it is better used in the compost heap where these substances can decompose without affecting plant growth rate. In my early gardening days, we used to gather seaweed from a beach that accumulated large amounts, particularly after a southerly buster.

Calcium

Calcium is usually applied to the soil to release other nutrients by altering the soil acidity (pH). It is said, on this account, not to be a fertiliser. Calcium is a structural part of the walls in plant cells and deficiency is associated with poor keeping quality. As well, it is essential for the proliferation of beneficial soil bacteria. Clay soils often become sticky if there is an excess of sodium. Calcium displaces sodium attached to clay particles, and since it is a much bigger atom, holds the clay particles further apart thus making the



clay more friable. While gypsum (calcium sulphate) is recommended to break down sticky clay, it will only work if the cause of the stickiness is excessive sodium. If the soil is also acidic, it is cheaper to use crushed limestone (calcium or magnesium carbonate). An excess of calcium relative to magnesium is generally accompanied by insect problems in the crop.

Sap tests of potatoes grown on pelletised poultry manure showed much higher levels of calcium than those grown on artificial fertiliser. Part of the reason for this could well be the very high level of potassium in the artificial fertiliser. Excessive potassium is known to produce calcium deficiency symptoms in some crops. These include deformed terminal leaves, buds and branches, poor plant structure, such as weak stems, celery black heart, lettuce tip burn, internal browning of cabbages, cavity spot in carrots and bitter pit in apples.

Calcium is generally applied as ground limestone (calcium carbonate), or dolomite (a mixture of calcium and magnesium carbonate). As referred to elsewhere in this book, calcium and magnesium in the soil must be in appropriate ratio. Liming to merely adjust pH may lead to excess calcium, or worse, if high magnesium dolomite is used exclusively, excess magnesium.

Sometimes, builders' lime (calcium hydroxide) is used for a quick response. The bulk of this is rapidly converted to calcium carbonate when it reacts with dissolved carbon dioxide in the soil water. It is probably more economical to use very finely ground limestone where a faster response is needed.

When the soil is badly out of balance, it is not a good idea to lime heavily. This has a deleterious effect on the soil microbiology. It is much better to apply frequent, lighter applications allowing the soil biota to gradually adjust to the changing environment.

Magnesium

Magnesium is the companion to calcium in mineral deposits. The carbonates of both are used as liming materials. However, in plant nutrition it is the companion to phosphorus and stimulates the assimilation of phosphorus by plants. It is essential for the formation of chlorophyll. Magnesium deficiency causes chlorosis in plants,

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Because work addiction keeps us busy, we stay estranged from our essential selves. An aspect of that estrangement is that we cease asking ourselves if we are doing our right work. Are we actually doing our true work, performing tasks or pursuing vocations that are good for us, for our families, for the universe?

—Diane Fassel

analogous to anaemia in animals. An excess of magnesium relative to calcium results in too high a pH, and consequent deficiency of many trace elements. In an emergency, Epsom salts (magnesium sulphate) can be applied as a foliar source of magnesium, but this is relatively expensive. Where the use of even high magnesium dolomite will still leave an excess of calcium over magnesium, there are several suitable magnesium sources; Kieserite (16% Mg), Magnesite (25% Mg) and magnesium oxide (50% Mg).

Sulphur

Sulphur is a neglected element in farming. This is difficult to understand, as it's essential for the formation of chlorophyll, proteins and vitamins. Perhaps it is because we rely too much on research conducted in the Northern Hemisphere, where sulphur compounds generated as pollution by industry arrive in the rain. These compounds, sulphuric and sulphurous acids, as well as hydrogen sulphide (rotten egg gas), are a fortunate rarity in Australia's relatively unpolluted atmosphere.

Sulphur can be applied to the soil as elemental sulphur. The usual source of sulphur for Australian farmers is superphosphate that contains more sulphur than phosphorus. Perhaps it would be better named super-sulphate! However, elemental sulphur is a much cheaper source when the phosphorus is not needed.

Hopefully, more work on necessary levels in the soil for particular crops will be conducted in the future. A high level of sulphur in a soil test is generally a symptom of poor soil aeration.

Trace Elements

Trace elements are those required in minute amounts for essential plant processes. Their availability is optimised when the soil pH is between 6 and 7, the major nutrients calcium, magnesium, potassium and sodium are in balance and the soil humus level is more than 3%. Absence or deficiency of particular trace elements may mean that enzyme cycles cannot be triggered into action, resulting in reduced crop performance, or even failure. Some trace elements are required for animal and human health without having any obvious influence on plant health, or productivity.

The assessment of trace elements through soil testing is an uncertain procedure. Measured levels that have been thought to indicate deficiency have been contradicted by the measurement of adequate levels in the plant tissue, and vice versa. Part of the problem is the fact that certain elements stimulate, or suppress, other elements. This is an area of soil science that is very poorly understood, and needs much more research. While tissue and sap testing offer the potential

for better assessment of crop needs, they too have their difficulties.

Trace elements are only poorly taken up by plants when they are in salt form. This has led to increasing use of chelated trace elements. Chelation (pronounced Key-Lay-Shən) means combined with an organic molecule. The compounds generally used are EDTA and ligno-sulphamate with the latter preferred. (EDTA is a suspected carcinogen). Of course, the trace elements in organic fertilisers, such as compost, pelletised poultry manure, liquid fish and seaweed, are already chelated, and often these materials, particularly seaweed and fish, contain sufficient trace elements for crop needs.

Manganese

Manganese is required in very small amounts and is very important, for without it, the production of amino acids and proteins suffer. It also works alongside magnesium in eliminating chlorosis. Soil with an excessive amount of magnesium and/or calcium locks up manganese.

Iron

Iron is essential for the formation of chlorophyll in plants and the prevention of anaemia in animals. Nearly all soils contain a lot of iron, unfortunately mostly in unavailable form. Soils treated with excessive amounts of superphosphate will often have excessive available iron, which reduces the availability of other trace elements. Maintaining good humus levels is beneficial in optimising the availability of iron.

Boron

Boron is implicated in the resistance of plants to diseases and is necessary for the formation of amino acids and protein. It is needed in only tiny amounts and many crops have benefited from the discovery that their potential was being limited by a deficiency. In the sap tests referred to earlier on potatoes grown under pelletised poultry manure, the boron levels were deemed excessive, whereas the sap tests from the conventional plot were deficient. The implications of this are unknown at this stage.

I think that most people want the word garden to be a noun which describes a place that you have set aside for your plants, so that the word gardening would be a verb that describes what you are doing when you work in your 'garden'. In my philosophy, garden is a verb; it is what you do. And, gardening is a noun that describes not what you did, but what you got when you gardened.

—Tom Clothier

Copper, Cobalt and Zinc

There remains much to be learned about this group of trace elements. Their deficiency is implicated in a number of animal diseases, steely wool in sheep and infertility in cattle among them. Plants deficient in copper show abnormal growth and stunted young branches. Zinc is essential for the formation of chlorophyll, but copper and cobalt also play a lesser role. Zinc deficiency is implicated in poor stock fertility.

Iodine, Chlorine, Fluorine, Sodium and Lithium

Iodine, chlorine and fluorine are all halogens. Iodine is well known as an essential ingredient in human and animal health as a regulator of metabolism. Plants readily take it up from foliar applications of liquid fish, or seaweed. It appears to have no major role in plant nutrition, or health.

Chlorine deficiency in plants is extremely rare. What is not rare is an excess caused by over-reliance on muriate of potash as a source of potassium. Excess chloride in soil tests is invariably accompanied by reduced availability of trace elements. Members of the rose family (*rosaceae* that includes pome fruit), are particularly sensitive to excessive amounts of chloride.

Fluorine is not considered essential for plant growth, but has an important role in animal nutrition. Both an excess and a deficiency are implicated in poor tooth development.

Sodium and potassium play complementary roles in plant and animal nutrition. Where potassium is deficient, sodium is absorbed in its place. Sodium is more often in excess than deficiency. Excessive sodium makes clay sticky. Gypsum (calcium sulphate) is often used to supply calcium, which displaces the sodium, allowing it to leach, making the clay more friable. Lime (calcium carbonate) is cheaper and can also be used where an increase in pH is desirable.

Lithium needs further study, but appears to be a companion to sodium and potassium. It has been applied to tobacco crops with the benefit of improving the quality of leaf grown for cigar wrappers.

Aluminium and Molybdenum

Aluminium is known more for the toxic effects of an excess than for any role in plant or animal nutrition. The conditions leading to toxicity are excessive soil acidity, reduced aeration and biological activity, and needless to say, low humus levels.

Isn't it enough to see that a garden is beautiful without having to believe that there are fairies at the bottom of it too?

—Douglas Adams

Molybdenum is essential for many plants. It serves as a catalyst in the early development of brassicas and appears to be essential in the fixation of nitrogen by bacteria. It is required in very small amounts. Excessively acid soil and low humus levels often cause deficiency. Excessive levels of molybdenum cause reproductive problems in livestock.

Cadmium and Lead

Cadmium and lead appear to play no role in plant nutrition, nor do they appear to be required for animal health. They are discussed here because they are toxic in excess, generally causing chronic disease, rather than outright poisoning. They are particularly problematic because the animal or person consuming them can only eliminate them slowly. This means that they tend to accumulate in the body over time.

Superphosphate used to be made from phosphate rock that was high in cadmium and lead. This means that soils heavily fertilised with this super can contain elevated levels of lead and cadmium and it is a cause for great concern that they are taken up by crops. The level of cadmium in sheep and beef kidneys has led to their being banned for human consumption in Western and South Australia.

In animal nutrition it is known that cadmium uptake is determined by food quality. Where the diet is deficient in zinc, cadmium absorption is increased. Other predisposing factors to increased cadmium absorption include periods of low nutrient intake and lack of high quality protein in the diet.

It is a matter for conjecture at this stage, but some organic farmers believe that increasing humus levels and bacterial activity in the soil reduces the uptake of heavy metals by crops.

Important Compounds

Enzymes

Enzymes are catalysts used by plants to manufacture cell tissue, trigger hormone reactions (flowering, leaf-drop etc) and take up nutrients. Most enzymes contain a trace element. An example is the use of molybdenum by the cauliflower. The enzyme requiring this element is only created in the first few days of the plant's existence. Application of molybdenum after this period has no effect on the deficiency symptom of "whip-tail" (aka "strap-leaf").

One of the most important resources that a garden makes available for use, is the gardener's own body. A garden gives the body the dignity of working in its own support. It is a way of rejoining the human race.

—Wendell Berry

Auxins

These plant hormones regulate cell division and elongation (i.e. plant growth and development). They are relatively unstable and are most readily created from complex organic compounds, such as those found in animal manures, fish and seaweed. They require enzymes for their formation.

Acidity

Soil acidity is the measure of the number of hydrogen ions in the soil (pH). When there are a lot of hydrogen ions, the soil pH is a low number. When there are few, the number is high. The neutral point is 7. Thus, pH less than 7 is acid, more than 7 alkaline.

Soil that is too acid, or too alkaline, locks up essential nutrients. A soil in which the calcium, magnesium, potassium and sodium are in appropriate ratio will have a pH between 6 and 7. This level of acidity is optimum for the availability of nutrients for most crops. A few crops prefer a pH between 5 and 6 and a small number tolerate alkaline conditions.

Soil Testing

Soil testing as a method of predicting crop yield is fraught with difficulty. Most soil tests used to ignore the importance of the balance between the major cations and the contribution of the organic fraction of the soil. You will find a crude organic matter figure derived by igniting the sample, but this does not reveal what proportion of that is humus. However, if you use the soil test result to bring the calcium, magnesium and potassium into balance, you will experience a long-term benefit to both the crops you grow, and the health of the consumers of your produce.

A major factor that affects humus formation is the balance of the major fertility elements calcium, magnesium, potassium and sodium. This discovery is attributed to William Albrecht who was Chairman

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Callused palms and black fingernails precede a Green Thumb. Work — the activity that interferes with gardening. When all the chores are done, the avid gardener will invent some new ones. Gardening dissolves mental chatter in the sweat of bodily effort. How can gardening be considered a "leisure time" activity? All play and no work makes Jack a dull boy — and a pain in the neck for others. We already live in the Garden of Eden, but we now have to work to keep it growing. By the garden one knows the gardener. To dig is to discover. The toil and sweat open ourselves to fruitful possibilities. The wise gardener knows when to stop.
—Michael P. Garofalo

of the Department of Soils at the University of Missouri, and the foremost authority on the relation of soil fertility to human health until his death in 1974. The relative percentages to optimise humification and consequently protein formation in most crops are:

- Calcium: 60 – 75%
- Magnesium: 10 – 20%
- Potassium: 2 – 5%
- Sodium: 0.5 – 3%
- All other cations: 5%

We have seen soil test results that show all other cations account for 40% of the total cations. This was a dairy farm and the livestock were in extremely poor health. Bringing the major cations into better balance with each other reduced the availability of the minor cations and stock health improved quickly and dramatically. The reduction in veterinary expenses more than paid for the change in fertiliser regimen.

Composts and Fertilisers

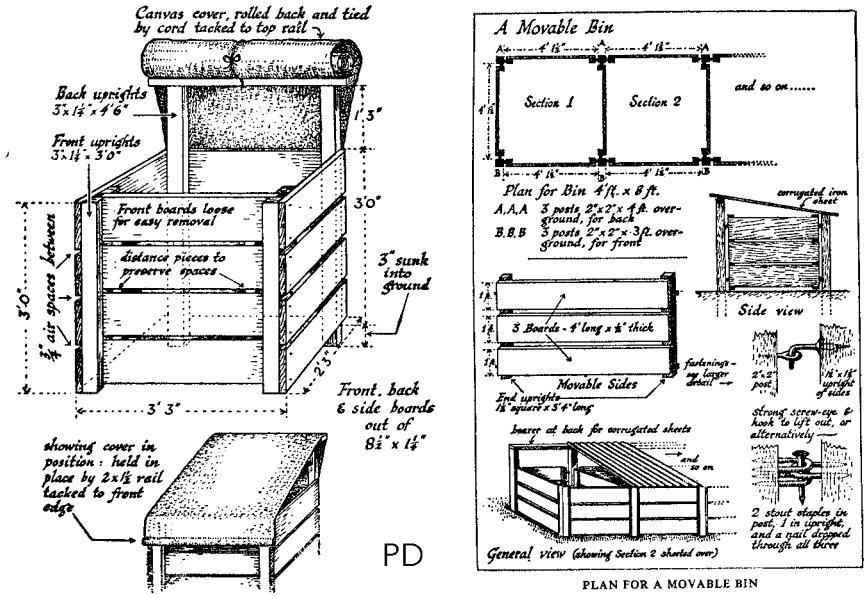
Intensive organic gardening requires a very high level of soil fertility, and that equates to continual inputs of large quantities of humus and mineral nutrients. The most economic source of humus is compost made on-site from raw organic materials: crop residues, sawdust, animal manures, hay, seaweed, in fact anything that was once living tissue. Composting is the controlled decomposition of the raw material and there are four main methods:

- Aerobic composting
- Anaerobic composting
- Vermicompost
- Sheet composting

All four methods require similar preconditions for success. There must be a source of cellulose (carbohydrate for energy), protein (the nitrogen source), lignin and other complex carbon compounds (the raw ingredients for humus formation) and water. The carbon to nitrogen ratio must be between 25:1 and 35:1. If there is insufficient nitrogen, the process will be too slow. If there is an excess, you will lose nitrogen in the form of the gas ammonia, readily detected by your nose.

If you grow a garden you are going to shed some sweat, and you are going to spend some time bent over; you will experience some aches and pains. But it is in the willingness to accept this discomfort that we strike the most telling blow against the power plants and what they represent.

—Wendell Berry



PLAN FOR A MOVABLE BIN

Aerobic Composting

AEROBIC COMPOSTING is far and away the most popular method. It has a number of advantages, chief of which are its rapidity and the development of sufficient heat to kill many weed seeds. The raw materials are placed in layers in a compost enclosure 1 – 1.5 metres (3–5 feet) square, or commercially in a windrow 1.5 – 2 metres (5–6 feet) wide and high. The length is as long as is convenient. The layers should be 25 – 50 mm (1–2 inches) thick and wetted to the consistency of a well wrung-out sponge. That is, squeezing a handful tightly, one gets the impression water is about to drip from it. If it does drip the material is too wet.

A traditional recipe is one-third animal manure, one-third fibrous material such as straw, and one-third *wilted*[12] green material. A comprehensive description of ingredients and their relevant properties is at the end of this chapter. The heap is initially invaded by the white hyphae of the fungi responsible for breaking down cellulose to simpler carbohydrates, the fuel for the thermophilic (heat loving) bacteria that subsequently take over. The temperature in the heap then rises to around 65°C. At this point, the compost is generating luxury amounts of CO_2 and it makes sense as Bill Mollison and I discussed so long ago to be piped into a greenhouse for immediate conversion back into plant tissue.

12 I found this essential for decomposition to commence quickly. As well, excessive amounts of unwilted greenery such as lawn clippings *can* become a slimy, maggot-infested mass according to some gardeners.

Almost anything that was once living can be composted. Meat however will attract rats.

The compost heap should be protected from rainfall, or it is liable to become too wet. While a fully roofed composting area is ideal, this is generally too expensive. Polythene covers of various sorts are frequently used, but this reduces the flow of air into the heap, so they need to be put on only in wet weather. Straw thatch allows air to enter and sheds water. When the straw becomes unusable for this purpose, it is incorporated in the next compost heap.

When the temperature of the heap begins to fall, the heap is disassembled and rebuilt, placing the material that was on the outside of the previous heap on the inside of the new heap. The temperature rises again to around 60°C and this ensures any undesirable organisms such as most weed seeds, pathogenic bacteria or antibiotics are destroyed.

Turning the heap frequently to produce finished material as soon as possible is called the Berkeley Method; turning the heap once, or twice only, the Indore Method.

The material can be used when the original ingredients are only barely recognisable. However, when the material is left for up to twelve months to mature, the humus becomes more stable and

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The work of a garden bears visible fruits—in a world where most of our labours seem suspiciously meaningless.

—Pam Brown

Free-form compost heap to the left and a three compartment bin above.

long-lasting in its effect. In practice, we all use much of our compost before it fully matures. Some composters believe that the compost is superior when the heap is run at the lower temperatures of 35–40°C. This would only be workable where there were few weed seeds to cause later problems. One notable common seed that survives the 60°C compost heap is that of white clover.

The temperature of the heap is controlled by altering its air content. Less air lowers the temperature — more increases it. Excessive temperatures caused by insufficient moisture can lead to scorching, or even burning of the material. Air content can be increased by inserting a perforated pipe through the centre of the heap, with, or without an air-blower attached. Decreasing air content is achieved by compressing the layers as they are built up. Improving aeration at the bottom of the heap, compacted by the weight of material above, may be achieved by using coarser material for the base, or even a simple brush-filled trench.

Insufficient moisture is indicated by excessive heat. Excessive wetness is revealed by the foul smells of anaerobic fermentation. Excessive nitrogen content is revealed by the evolution of ammonia; insufficient nitrogen by the low temperature achieved. While it would be entirely possible for you to use tables of nitrogen and carbon content of the various possible materials used in compost, I know of no one other than research scientists who would bother. In practice, we all use a fairly restricted range of materials and learn the correct ratios by trial and error. Making excellent compost is as much an art as it is a science.

When I go into my garden with a spade, and dig a bed, I feel such an exhilaration and health that I discover that I have been defrauding myself all this time in letting others do for me what I should have done with my own hands.

—Ralph Waldo Emerson

While there is a wide range of compost inoculants and activators on the market, they are almost all pretty much pointless. The spores of the bacteria and fungi needed for composting are present everywhere, especially in the soil the heap is built on. One way to test the need for them is to build one heap from raw ingredients alone and one inoculated with some finished compost and comparing the results. I did run a trial of composting chicken manure with sawdust using the Biodynamic compost preparations and a commercial inoculant. Using them definitely decreased the time required to finish though not by very much.[13] However, that would only be an issue if you needed to use the compost before allowing it to mature. As to the "special" properties of Biodynamic compost, I remain largely unconvinced.

A compost heap that should be progressing rapidly, but is nevertheless sluggish, could be for the following reasons. If the weather is very hot, the flow of air through the heap slows down. Cold air outside the heap allows what is called the chimney-effect to draw air through the heap as the hot air within rises. In typical south east Australian conditions, winter-time is best for compost-making.

The other possibility is that the ingredients are too acid. If the ingredients you regularly use fall into this category, you should dust some of the layers with very finely ground limestone, much as if you were dusting a cake with icing sugar. It is not necessary to use builders' lime (calcium hydroxide); it is rapidly converted to limestone (calcium carbonate) in contact with moisture and carbon dioxide, which are abundant in the compost heap. Do not apply the limestone directly on the animal manure or you will convert the nitrogen content to ammonia, with the distinct probability it will be lost to the atmosphere.

Compost-making is probably the most energy-consuming task for the market gardener and design of the compost area calls for some planning to make it easier. If possible, the raw materials should be accumulated at the top of a slope. The heap assembled immediately below and the rebuilt heap below that. This allows gravity to assist us. On a large scale, a scoop mounted on the front of a tractor would appear to be essential. While purpose-built machines for composting exist, they are very expensive.

Since the speed of decomposition of the component materials in the compost is dependent on their surface area, shredders are often used to pre-process the ingredients. The shredding of materials such as tree branches and cabbage stalks is probably economically justifiable if there is a sufficient amount. In any event, a heavy-duty shredder is more likely to pay for itself than the home garden variety. If

13 Just a few days. The compost took 12 weeks to the point of usability.

you feel you need such, you are probably already using a tractor and this makes the sort run from the tractor's PTO a better proposition. That said we acquired a home garden shredder a couple of years ago and use it to shred prunings from the orchard and decorative shrubs. This material is directed at the base of the trees and shrubs as mulch, rather than in our compost heaps.

In the home garden, cabbage, broccoli and Brussels sprouts stalks

Vic Check shows us the worm farm where he added the Biodynamic herbs and the hoofs and horns of cattle. It looked just like BD Preparation 500. Steiner had said in his lectures that hoofs of cattle were just as effective in transforming cow manure into Preparation 500 as horns, just not so suitable as containers.

can be mashed flat with a heavy hammer, or the back of an axe blade to speed their breakdown. Untreated they survive composting for a surprisingly long time.

Anaerobic Composting

It will surprise many people, but the centre of an aerobic compost heap becomes anaerobic within minutes of assembly. All the oxygen is used up. However, the aerobic portion migrates toward the outside and some part of the heap is always decomposing aerobically. Anaerobic composting is decomposition of all the ingredients in a complete absence of oxygen. This leads to foul smells, so it is just as well that the elimination of oxygen requires sealing the material within a container. In the aerobic heap, the foul smelling substances are broken down as they pass into the surrounding aerobic region. Anaerobic composting proceeds much more slowly than aerobic as it is a cold process. The temperature rise in aerobic composting requires oxygen for the thermophilic bacteria.

Having said all this, you may wonder why we are discussing anaerobic composting at all. The special purpose where you may decide to compost anaerobically is when you want the biogas (methane) that evolves for fuel. This I have never done, so I do not propose to do more than indicate it as a possibility. The finished material has higher nitrogen content than aerobic compost, but it still really needs processing through an aerobic compost heap to stabilise the nitrogen compounds as protein. I note that a lot more methane is evolved from plant material than animal manures. In India where methane is a common fuel, it's called Gobar.

Vermicomposting

This imposing word merely means the use of compost earthworms to turn your raw materials into compost. Certain materials, such as sheepskins, are difficult to process any other way. Unlike a conventional compost heap, the materials are generally placed in a container that is vermin-proof. This is a cold-composting process, so the heat generated in a conventional heap is not available to prevent vermin from invading. It is also wise to include a method of preventing the escape of the earthworms, which they are prone to do if you are not spot-on with the provision of ideal conditions for them.

My original vermicompost unit was a discarded bathtub with

The only thing that endures over time is the "Law of the Farm". You must prepare the ground, plant the seed, cultivate, and water if you expect to reap the harvest.

—Stephen R Covey

several layers of mesh over the plug-hole. The tub was covered with a sheet of marine plywood and this kept the rats and mice out. Earthworms require the ingredients to be somewhat wetter than in a normal compost heap, so the volume of material must be considerably smaller in cross-section to prevent the anaerobic condition worms will not tolerate. As well, careful attention to pH is required as earthworms have a strong aversion to acidity. Frequent additions of lime are invariably required. Two materials that worms will tolerate in only small amounts are citrus peel and onion scraps.

The vermicompost unit should be placed where it will remain between 15 and 25°C. Worms cannot tolerate temperature extremes. Light is another enemy of earthworms, so a lightproof cover is essential. A fully functioning vermicompost unit will process the addition of approximately 2.5 cm (1") of fresh material per week. To access the finished material, the fresher material on top is pushed to one side and the worm-casts removed. This material is an effective amendment to the soil at a considerably lower rate than ordinary compost.

The liquid that drains from the bathtub collects in a watering can and is used as a soil drench around hungry crops to great effect.

Sheet Composting

In sheet composting, the raw ingredients are spread over the area you wish to compost. The total thickness of the material should be no more than 30 cm (12"), or it is difficult to wet thoroughly. If it is less than about 20 cm (8"), it is difficult to maintain at a high enough moisture level. While it eliminates double-handling of materials, it is harder to manage than aerobic composting in a heap. Decomposition is slower, as far less heat is generated. Weed seeds can also be a problem. In market gardening, it is most likely to be used at the beginning, before the beds are raised. We use a cover of weed mat, or discarded carpets to help retain moisture and encourage earthworms. The weed mat is attached to treated-pine half round logs to prevent it blowing away. Sadly, it also encourages slugs and snails.

Compost Ingredients and Fertilisers

One of the most important ingredients for compost is protein (for its nitrogen), and it is the most expensive. Many gardeners believe that the disease resistance of crops is enhanced more by animal protein than vegetable protein in the compost; others disagree. Nevertheless, animal manures are a staple ingredient in most compost heaps.

All gardeners need to know when to accept something wonderful and unexpected, taking no credit except for letting it be.

—Allen Lacy

Liquid Fertilisers

Some organic practitioners are very much against the use of liquid fertilisers, either as soil drenches, or as foliar applications. The nitrogen in liquid manures is far more available than in regular compost and so is more akin to artificial fertiliser. They dislike foliar applications of fertiliser on the grounds that plants were designed to absorb nutrients through their roots, not their leaves.

The first point is an important one. It is entirely possible to replicate the disadvantages of artificial fertilisers with either raw animal manure, or liquid organic fertilisers. However, soil drenches of highly diluted material have effects far beyond the what the nutrient content analysis indicates. Many materials seem to have a more pronounced effect at high dilution rates than when more concentrated. Likely this is because the plant is responding to hormones, or hormone-mimics in those ingredients.

The second point is really ideological. If plants were not designed to absorb nutrients through their leaves, then it would not be possible for them to do so. Some plants, notably Spanish moss, have no roots in the soil and clearly make a living from atmospheric nutrients alone. In any event, what we apply as foliar feeds are nutrients in vanishingly small amounts. We do this not to supply the plants' needs for major nutrients, but for trace elements and the effect of these nutrients on certain micro-organisms that live on the leaves of crops and protect them from undesirable fungi and frost.

Liquid manures are easily prepared from raw ingredients by steeping them in water for a period of several days to several weeks, depending on their nature and air temperatures. On a small scale, the best vessels to use are plastic 200 litre drums with the tops cut off. Make sure that the drums you acquire were not used to store toxic materials. Plastic has pores that tend to hold on to the materials that were stored in them. Steel drums are useless, as they rapidly corrode, and the iron goes into solution.

Loosely woven bags[14] to hold the ingredients are useful to avoid later filtration, but require regular squeezing to ensure complete decomposition. The foul smells of anaerobic decomposition are reduced by regular vigorous stirring to incorporate air, which drives off the smelly nitrogenous compounds. This also reduces the nitrogen content incidentally, which somewhat takes away from the argument of the anti-brigade. The inclusion of chamomile is also said to reduce bad odours.

14 Synthetic cloth makes a useful material for this as natural fibres rapidly decay.

In use, the material is strained to remove particles that could block the equipment used to apply the liquid, and diluted as required. Some materials, particularly seaweed, are noticeably more effective at a dilution rate of 1000:1 than at 50, or 100:1. The optimum rates will need to be determined by trial and error, there having been little formal research at the time of writing. In any event, the ingredients you use are hardly likely to be consistent with those used by others, or even from season to season.

Animal Manures

Fill a bag with animal manure and steep in the drum of water, squeezing daily for three to five days. Dilute to the colour of weak tea and use as a foliar application to combat fungal disease. It is also useful as a side dressing to stimulate growth in spring when the soil is still cold and biological activity sluggish, or pre-plant soil drench.

Animal manure in its raw, initial state is generally frowned upon as a soil amendment. Much of the nitrogenous content is water soluble and hence susceptible to being leached into groundwater. As well, it is caustic and can burn plant roots. Animal manure can be stacked and left to mature before use, but this risks losing much of the nitrogen through the action of denitrifying bacteria. This does not happen in a well-managed compost heap and the nitrogen is stabilised therein as bacterial protein.

There's a possible exception here and that is cow manure. One source claimed that more than 95% of nutrients were still present in cow pats some nine months after they were deposited. I suspect that this was under dry summer conditions. Cow pats on our pasture tend to be hollowed out by earthworms within three to four months.

Blood 'n' bone

This is the most famous of all organic fertilisers. Unfortunately it has a number of disadvantages. The nitrogen in it is quickly made available in all but very cold soil, so it is a useful side dressing. Its fibre content is nil, so it is not a substitute for compost. The bone component slowly releases phosphorus and calcium.

Bone meal is also very smelly, an issue for some. The swimming pool the writer swam in as a youth was next door to the town's bone yard.[15] Before becoming a swimming pool, it had been a sewage treatment pond!

Despite its popularity in the home garden, it is difficult to justify the expense of what would otherwise be an excellent source of phosphorus, calcium and nitrogen. The problem arises because it is such

15 Nuneaton, Warwickshire, UKLand.

a valuable protein source for poultry and pigs, and this generally keeps the price high. Our chickens were fed ad lib blood 'n' bone, wheat and free range pasture. They spent the night and morning in a shed where they pooped on the sawdust deep-litter that was then used in the compost. From mid-day to dusk they were free to roam until a neighbour's dog took to killing them.

Apart from my early days of gardening when I didn't know any better, I have not used blood 'n' bone as a soil amendment, nor do I recommend it. If you do use it, be aware that it needs to be incorporated into the soil rather than used as a top-dressing. Sunlight will rapidly denitrify the protein and your nitrogen will be lost as nitrogen gas.

Chicken Deep Litter

We were using tens of cubic metres of compost a year on our market garden. At that time the cheapest source of nitrogen was chicken deep-litter from commercial grower sheds. This was a mixture of partially decomposed sawdust and chicken manure. Upon arrival at the farm it had to quickly be wetted and mixed with other compost ingredients or most of the excess nitrogen content would have gone to waste. There was also the danger of it catching fire.[16]

There are some who disapprove of this invaluable fertiliser material on the grounds that it's unkind to chickens to run them on deep litter. The writer disagrees unless the chickens are overcrowded. Our own hens loved scratching around in the deep litter and according to a rather ancient poultry keeping book I read obtain a significant amount of essential nutrients from the material.

Chicken deep litter is best mixed with cereal straw and composted. The straw will prevent the loss of valuable nitrogen and the straw decomposition products include mucins, glue-like compounds that bind soil into relatively stable crumbs.

Coal

There are several types of coal: lignite and anthracite are the main sorts. Anthracite is nearly all carbon and quite expensive. Lignite is also known as brown coal, the cheapest sort, and very useful in gardening. The carbon in lignite is in the form of a precursor to humic acid, the substance we create in our compost heaps. There is a grade of coal called Leonardite where the formation of humate is complete, but that is rarer than lignite. Crushed coal is then a useful soil supplement

16 I was told by a South Australian firefighter at a seminar the disastrous fires in South Australia at the time were started by a compost heap that spontaneously combusted. I have been corrected in this, but spontaneous combustion of compost heaps is far from unknown.

where it is cheaply available. Unfortunately that doesn't include where I live so I've never had the opportunity to try it for myself.

I have however used an extract of Leonardite called Humilac and it was a remarkable material that was applied at a very low rate to the soil where it encouraged the humification of plant remains. We used it in a number of field trials in conjunction with green manure prior to growing onions. Both the yield and quality were greatly improved when compared to green manure alone. I'm led to believe it was particularly valued by cannabis growers for it enhanced the formation of the active ingredient tetrahydrocannabinol (THC).

Comfrey and Nettles

We have used a mixture of comfrey and nettles for the stimulation that nettles provide plants growing sluggishly in cold spring soil and the potassium content of the comfrey. We filled a plastic drum with equal parts of both and topped up with water. It smells very much like pig slurry—bloody awful! However, we find it of great benefit as a soil drench, particularly for tomatoes and pumpkins.

Compost

Fill a bag with finished compost and steep in the drum of water, squeezing daily for three to five days. Dilute and use as a foliar application to combat fungal disease. A trial in New Zealand when the author was just a beginning gardener gave excellent results combating apple scab (black spot).

Commercial Compost

I have used several different commercial composts. The best was composted Lucerne (alfalfa) made locally and delivered in bulk in a ten tonne truck. I have also used bagged composted pine bark for growing in containers from the hardware store. This was successful for small crops like lettuce and strawberries, but not so effective for tomatoes and capsicums. It ran out of "oomph" before the crops were fully mature.

I have also used spent mushroom compost in the garden in conjunction with home-made fertiliser. The mushroom compost was delivered in the bags the mushrooms were grown in and used to grow several small crops of mushrooms before being consigned to the garden. Without the mushroom harvest, it's a tad expensive and most of the nutrient content has gone into the mushroom harvest. It does however provide plenty of humus for soil improvement. I note that locally at least it's made from chicken deep-litter and straw.

A thinking human, that does, is worth fifty that just eat.

—Richard Perez

Cottonseed Meal

Cotton-seed meal is very bulky for its weight and so is uneconomic to transport over long distances. Where cheap transport makes the cost realistic, it is a very useful nitrogen source, both directly in the soil, or as a compost addition.

Cow Manure

This is rated second only to horse manure in value for the compost heap, though the author rates it above all other manures. It is just as fibrous as horse manure, but is lower in nitrogen content. In the paddock, it retains much more of its nutrient content than horse manure. Biodynamic practitioners would not dream of making compost without it.

Fish

Fish, like seaweed is full of trace elements. Fresh fish is best, rotten fish smells deplorable, but it's just as good for the compost heap. Dehydrated fish-meal is expensive. Liquid manure made from any fish you can get is probably a better use than in the compost heap. Commercial fish emulsion (liquid fish) is usually too expensive to use as a compost activator unless purchased in bulk.

Home-made fish emulsion smells even worse than comfrey and nettle. As a consequence, we use a better smelling commercial fish product. We once were given several large containers of fish meal that had not been completely cooked due to the cooker breaking down. At the time we didn't have an immediate use for it in the garden and so top-dressed an acre of extremely poor pasture with it.

The result was astonishing and the change from poor pasture to quite acceptable was rapid. Ground that had been dominated by bracken fern started producing decent grass feed instead.

Fish Emulsion

Fish emulsion is the most useful of organic fertilisers. It is sold in a range of qualities and at a range of prices. The best we have used, Vitec, was much cheaper than liquid seaweed and unlike some fish emulsion we have used, pleasant smelling. The worst (smelliest) and most expensive we have trialled, needed filtration prior to use. It appeared to contain scallop frill (short fibres) that clogged the sprayer if not removed.

Those who see worldly life as an obstacle to Dharma see no Dharma in everyday actions; they have not discovered that there are no everyday actions outside of Dharma.

—Zen Master Dogen

Fish emulsion applied as a soil drench at rates of around 6 ml per square metre releases many nutrients from the soil. Applied as a foliar spray at dilution rates of 50 to 1000:1, it inhibits many fungal diseases. Regular application at 10–14 day intervals is more beneficial than less frequent, more concentrated applications. One of our neighbours, a conventional apple producer, established a cherry orchard. The only fertiliser used in it was foliar fish emulsion. The flavour of the cherries were superb, but after three summers in a row of rain at harvest time,[17] he sold up and retired.

Ted Sloan and Vitec Fish Emulsion

I met Ted in the early 1990s. He was from New Zealand where he'd been an agricultural extension officer. He decided to implement some of the advice he's been giving out by starting a kiwi-fruit (Chinese gooseberry) orchard. This was in the early days, a few years after New Zealand growers decided to rename the fruit and engage in a highly successful campaign to market this delicious and prolific fruit.

By religiously applying the advice he'd been handing out for several years, Ted succeeded in having the highest yield of any grower in his district. Unfortunately Ted discovered that wasn't sufficient to ensure financial success. His fruit had the highest break-down rate in storage!

A clue to the underlying cause of this came when he was burying the dead family cat in the home garden. Unlike the orchard, the soil was alive with earthworms and far better structured. As it happened, Ted's background was in chemical engineering and he decided that what the orchard needed was a source of organic matter that would encourage earthworm activity.

The cheapest source of organic matter to hand was fish scrap from a nearby fish processing factory. Ted set about developing a way to make applying this to the crop work. The usual methods included mechanical maceration, chemicals and/or heat. Ted decided that a biological agent was called for and he was (naturally) a little coy about the exact nature of his approach. Ted's fish emulsion was produced extraordinarily rapidly and with minimal energy input. The resultant product was inexpensive compared to many rival fish emulsions and far, far better smelling.

Vitec fish emulsion not only smelt OK. It tasted pretty good too! A Japanese food manufacturer expressed interest in using it as a raw input for their fish sauce. It was stabilised with phosphoric acid (an ingredient in many processed foods) and was readily certified

17 Rain on the cherries makes them split rendering them worthless. Rain covers are used but they are very expensive. Hiring a helicopter to dry the wet cherries costs a great deal also.

organic by the Biological Farmers Association.

When he used the emulsion on his kiwi-fruit orchard, the most noticeable outcome was the rapid disintegration of the fallen leaves that had hitherto collected in deep drifts. The soil came alive as the earthworms invaded and Ted's fruit stopped rotting in storage. Unfortunately for Ted, the price for kiwi-fruit dropped precipitously as the many start-up kiwi-fruit producers started to harvest the fruit. It's a phenomenally heavy cropper.

Ted realised however that he had an interesting new product from which he could make a living. Vitec worked either as a soil drench, or as a foliar fertiliser. One of the problems of pasture production is called pulling. Sheep and cattle grazing on grass in winter tend to pull the grass plants out of the soil as they eat it. This greatly reduces grass production and the gaps left tend to become populated by weeds, usually inedible ones. Vitec encouraged grasses to develop much deeper root systems and stock indicated their preference for feeding on organically-fed pasture as they have done in ever so many other places and times.

One remark that the writer recalls Ted making was that the best farmers had a similar attitude towards the soil with the best home vegetable gardeners. Lionel Pollard, the founder of Willing Workers on Organic Farms (WWOOF)[18] in Australia also made an interesting statement. He'd been a guest on a farm in East Gippsland and his host had apologised for serving a meal of roast beef without potatoes as they had run out. "But you're a potato farmer!" Lionel had remarked. "You've got acres of potatoes on the farm!"

"Oh, we wouldn't dream of eating anything we grow for the market," said the farmer, "We have run out of potatoes in the home garden." It's hard to imagine an organic farmer making such a remark.

Grass Clippings

Grass clippings from lawns are a good source of nitrogen. They have a tendency to form a slimy, impervious mat if layered too thick. Keep layers of grass clippings no more than about 2.5 cm (1") thick and make sure they are well-wilted before use either in the compost heap, or as a mulch.

Hay

On the surface, hay looks like an ideal compost ingredient. It is high in fibre and lignin, and has significant protein content that cereal straw lacks. However, much hay is made with grasses at the seeding stage, so weed seeds can be a great problem. I have used

18 WWOOF in the UK was the acronym for Working Weekends on Organic Farms.

hay extensively, and with care, it has been invaluable. Lucerne hay is much less problematic in this regard, and it has a higher protein content than grass hay. Lucerne also contains valuable growth promoting auxins. In districts where a second hay cut is taken, the second cut contains far less seeds.

When we used hay as a mulch it we left it in "biscuits" and that made it easier to flip over when the weed and grass seeds germinated.

Hop Mark

The material that remains after the hop flowers have been removed makes an excellent compost ingredient. I imagine that following the success of an organic hop growing trial at Tasmania's largest hop farm about thirty years ago, you'll be lucky to obtain any. While the production of hops organically never went anywhere at the time, the advantages of stimulating the proliferation of earthworms were manifest in the trial.

Horse Manure

Horse manure is very high in both fibre and nitrogen content as horses are very inefficient users of the nutrients in their food. A good source of horse manure is from racing stables. As very high protein diets are fed to racehorses, their manure is also highest in nitrogen. The manure will in all likelihood come already mixed with fibre of some sort, generally sawdust, or wood shavings. Care must be taken to ensure it is not contaminated with wood preservatives, such as copper-chrome-arsenate, or the solvents and glues used in woodworking. Horse manure is generally rated number one for market gardening.

Human Manure

It is illegal to use human manure on the soil or in compost used to grow food for human consumption due to the possibility of contamination with several intractable human diseases. This doesn't stop people from using it. With care, long periods of decomposition, and attention to where it's used, under trees for instance, they seem to experience no difficulties.

In his garden every man may be his own artist without apology or explanation. Each within his green enclosure is a creator, and no two shall reach the same conclusion; nor shall we, any more than other creative workers, be ever wholly satisfied with our accomplishment. Ever a season ahead of us floats the vision of perfection and herein lies its perennial charm.

—Louise Beebe Wilder

Leaves

Most tree leaves are low in nitrogen and high in tannin, which slows decomposition. Use only moderate amounts in compost, or let them decompose in their own heaps without additives for two years or so. The resultant material, called leaf mould, is an excellent substitute for peat-moss. Eucalyptus leaves contain oils and other substances that render them somewhat less useful than European deciduous trees, so treat them with caution. The University of California recommends composting them separately and testing the effect of the resultant compost on seed germination. Pine needles contain terpenes, the raw ingredient for turpentine, so use them sparingly.

Lucerne (Alfalfa) Chaff

Lucerne chaff is Lucerne hay that has been chopped up small for use as stock food. It can be applied directly to the soil and lightly tilled in for a quick nitrogen boost. It also contains hormones that increase the rate of growth.

Paper

Newsprint contains lignin as well as cellulose so it is better than higher quality papers consist entirely of cellulose. The coating on coated paper is mostly clay. Paper should be shredded before use, to prevent it forming layers impervious to water. Many composters avoid paper printed with coloured inks as these may contain undesirable contaminants such as heavy metals. Despite the printing industry replacing many heavy metal pigments with safer ones, in 2010, 20 years later, an analysis of paper used for food packaging found lead, chrome and mercury.[19]

Pea Straw

Pea straw makes an excellent compost ingredient, or feeding mulch being high in nitrogen. A few viable pea seeds will germinate in it when used for mulching, but they are easily removed by pulling them out by hand. Pea straw tends to be on the expensive side because it's also useful animal feed.

Phosphate Rock

The phosphate rock that is used to manufacture superphosphate was all that was available in years past. Now we can buy *reactive* phosphate rock (RPR), in which the phosphorus is more readily available to crops. Phosphate rock can be applied directly by incorporating it into the soil, or via the compost heap.

19 Xue, M. & Wang, S. & Huang, C.. (2010). Determination of heavy metals (Pb, Cd, Cr and Hg) in printed paper as food packaging materials and analysis of their sources. Huagong Xuebao/CIESC Journal. 61. 3258-3265.

Pig Manure

Pig manure is considered little better than poultry manure, as it is devoid of fibre. Past pig-farming practice was to include a copper supplement to make the pigs grow faster. As a consequence, pig manure often had an excessive copper content and this is detrimental to earthworm health. We advise caution and make sure you know what's being fed to the pigs whose manure you are using.

Poppy Seed Meal

As for cotton-seed meal above though you are unlikely to find this outside Tasmania (or Afghanistan).

Poultry Manure

Like horse manure, poultry manure is rated as "hot". That is, it is very high in nitrogen. Unlike horse manure, it is devoid of fibre, which is why market gardeners generally rate it last in the list of desirable animal manures. However, the writer's garden has thrived on compost made from chicken deep-litter (poultry manure mixed with sawdust) and crop residues. Poultry manure is generally free of weed seeds. Antibiotics are a common additive to poultry diets in modern intensive units. As they are very unstable compounds they generally should not be a problem in an aerobic (hot) compost heap.

Pelletised Poultry Manure

Materials such as the well-known *Dynamic Lifter* and *Organic Life*, consist of chicken deep-litter composted, pelletised and steam sterilised. Some products are blended with fish, seaweed, blood 'n' bone, other animal manure, or zeolite to improve the material. These products are necessarily a lot more expensive than the compost you can make for yourself. However, they do have the advantage of being much easier to handle and spread with machinery. They are generally most useful when your own composting program has fallen behind or you are a beginning gardener. This material is well-suited to direct use by incorporating it into the soil.

Rock Dusts

Various crushed rocks can now be purchased for use in improving soil fertility. Basically, the theory is to emulate the effect of glacial action on rocks that form silt. Rather than wait for another ice age,

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My passion for gardening may strike some as selfish, or merely an act of resignation in the face of overwhelming problems that beset the world. It is neither. I have found that each garden is just what Voltaire proposed in Candide: a microcosm of a just and beautiful society.

—Andrew Weil

we crush the rocks containing the desired minerals and apply them either directly to the soil, or via the compost heap. To be effective the rock has to be very finely powdered so as to present as great a surface area to the soil organisms as possible. You may find that the nearest road-metal quarry will let you take the fine stuff away for free. It tends to accumulate below conveyor belts and such like. Some unscrupulous vendors mix clay with rock dust to improve their profit margins, so beware.

One enterprising quarry owner had me test the fine rock powder he was collecting and I was happy to report excellent results from inclusion in the compost. It is well-suited to direct incorporation in the soil where the crops are to grow. Being slow-acting, the effects will not be immediate and will last well beyond the first crop grown after application.

Sawdust

Sawdust gets a pretty bad press in gardening circles. However, it can be an excellent source of fibre, cellulose and lignin. Softwood sawdust contains terpenes and resins that are growth inhibitors, so we have only used eucalyptus hardwood sawdust. Sawdust from workshops may contain synthetic glue residues, so we have always used sawmill waste. Sawdust from decades old heaps is nearly all lignin, but it is generally wet, and therefore heavier and harder to move than dry, green sawdust. Sawdust must never be incorporated into the soil. Where it's used as a mulch, the soil should have compost incorporated first, or possibly blood 'n' bone. Decomposing sawdust will tie up a lot of nitrogen while it's decomposing.

Seaweed

Seaweed contains neither cellulose, nor significant nitrogen. Nevertheless, it is an important ingredient in gardening. It contains the

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Anthropocentric as [the gardener] may be, he recognizes that he is dependent for his health and survival on many other forms of life, so he is careful to take their interests into account in whatever he does. He is in fact a wilderness advocate of a certain kind. It is when he respects and nurtures the wilderness of his soil and his plants that his garden seems to flourish most. Wildness, he has found, resides not only out there, but right here: in his soil, in his plants, even in himself...

But wildness is more a quality than a place, and though humans can't manufacture it, they can nourish and husband it...

The gardener cultivates wildness, but he does so carefully and respectfully, in full recognition of its mystery.

— Michael Pollan

full range of trace elements and is a moderate source of potassium. If you are lucky enough to be near the seaside, you can collect the material yourself where that remains legal. Bull kelp is said to be the best. Unfortunately, wet seaweed is nearly all water. Seaweed for sale is dehydrated. We have used both and the convenience of seaweed meal outweighs the inconvenience of heavy, wet, smelly seaweed half an hour's drive or more away.

Analysis of kelp meal by Mount Pleasant Laboratories of Tasmanian Department of Agriculture. File H047. Lab No 20172.

- Nitrogen: 0.750%
- Sulphur: 0.695%
- Phosphorus: 0.196%
- Zinc: 88.3 ppm
- Potassium: 1.36%
- Boron: 70.0 ppm
- Calcium: 1.08%
- Iron: 53.9 ppm
- Magnesium: 0.882%
- Manganese: 61.5 ppm
- Sodium: 2.93%
- Copper: 2.50 ppm

Some seaweed gatherers scrupulously "wash the salt off" their freshly gathered seaweed before use. Most of the salt from the seaweed has already washed off in the rain. Also it's not just sodium chloride, but many different salts. One organic grower of my acquaintance, Ray Mason, used to apply dilute seawater as a foliar spray on crops. He also gave dilute seawater to his dairy cattle. He was an excellent farmer and useful mentor when this writer was first learning the tricks of the trade forty years ago.

Seaweed Meal

Seaweed meal is available in various grades. The powdery sort sold as stock feed is less satisfactory than the coarser grades that are less inclined to blow everywhere in the wind. Application rates between 75 and 150 gm per square metre (2–4 oz per square yard) are ample. Rates much higher than this recommendation have the lamentable effect of depressing yield. The benefits to expect are improved trace element availability and water-holding capacity of the soil.

"You are right," said Pangloss, "for when man was placed in the Garden of Eden, he was placed there ut operaretur eum*, to dress it and keep it; which proves that man was not born for idleness."*

—Voltaire

Seaweed Emulsion

Liquid seaweed is the single most popular liquid fertiliser. It contains substances, such as abscisic acid, the plant hormone that tells deciduous trees to drop their leaves. This material is implicated in seaweed's ability to confer disease and frost resistance to crops. Seaweed also contains plant growth hormones (auxins) that influence cell elongation and division. To cap all this off, it also contains the full range of trace elements in a form readily available to plants.

To make a liquid fertiliser with fresh seaweed, fill the drum completely and top up with water. To use seaweed meal, use about 10 kg (20 lb) or so to 200 litres (53 US gallons). Seaweed breaks down very rapidly as it contains alginate, rather than cellulose in its cell walls. We use it diluted to the colour of very weak tea.

Sewage Sludge

This otherwise excellent source of nitrogen is often contaminated with heavy metals due to sewage and storm-water sharing the same drains. As we become more aware of the waste of this resource, the situation is hopefully going to change. Sadly, I have been saying this for more than 30 years now. Best used as compost activator where the heat will destroy most pathogens.

Sheep and Goat Manure

To all intents and purposes, sheep and goat manure are the same material. It is fibrous and moderately endowed with nitrogen. When we kept goats, my wife made perfect compost on her first attempt using goat manure mixed with hay the goats had refused to eat. They are very picky eaters despite a reputation for eating anything. Due to their dietary habits, these manures are nearly always full of undigested weed seeds, so careful attention to turning the heap to kill them is required.

Aged sheep manure is commonly available in wool-producing districts as large amounts accumulate under the shearing sheds. Some gardeners use it directly on the soil, but the weed seeds are a problem best avoided by incorporating sheep manure in the compost heap.

Straw (Cereal)

This is a major source of fibre and lignin. Except for legume straw, it has virtually nil protein content. Weed seeds are rarely a problem in straw. Decomposing cereal straw produces substances called mucins that act as a glue to improve the stability of soil crumbs. Straw should never be incorporated directly into the soil unless it's accompanied by a source of nitrogen. It makes almost perfect mulch and is excellent when composted.

Vegetable Scraps

A market garden will produce an abundance of material unsuitable for sale; leaf trimmings, pea haulm etc. The leafy material is best wilted to accelerate decomposition when composted, the denser material for vermicompost, and most can be used directly in the soil.

Weeds

Weeds are wonderful accumulators of various trace elements. Before incorporating them in the compost heap, they must be wilted, or they take much too long to break down. Weeds at the seeding stage can be a source of further weed contamination if they are not heated to a sufficiently high temperature, or if their seeds can tolerate compost heap temperatures. For example, wild white clover seeds can survive 65°C.

Weeds contain a wide variety of trace elements that are useful to our crops. Biodynamic practitioners claim that making liquid manure out of your weeds and spraying it where they are a problem reduces the problem. Even if this is not true, you will be doing your crops a nutritional favour.

Wool

We used to compost all the loose bits and dags[20] after shearing our sheep flock. Wool is an excellent nitrogen source. This material can be used directly in the soil, or the compost heap.

Producing Your Own Compost Ingredients

We have produced our own hay, goat, sheep and chicken manure. Goat manure is convenient due to the habit of goats defecating in the sheds they require for shelter from inclement weather. As well, they are very wasteful of hay and this becomes mixed with the dung. It is unfortunate that goats spend 95% or more of their intellectual abilities planning the best way to invade your garden.

We kept chickens for eggs in a shed on sawdust during the morning, allowing them free-range in the afternoons after they had finished laying their eggs. The shed was cleaned out once a year in the summer, and this material was our profit margin due to the low price for eggs and the high price of wheat at the time.

We would have liked to establish a paddock of Lucerne, far and away the best fixer of atmospheric nitrogen, but our soil is too heavy for that. An alternative would have been cow grass, a heavy yielding

20 The sheep's dags are the mixture of wool and faeces that accumulate around the animal's rear end. This material became far less common with the introduction of mulesing. Now that mulesing is becoming forbidden, dags are again in plentiful supply to the probable delight of the flies that lay their eggs on daggy sheep.

red clover. We do grow comfrey and stinging nettles, both being of inestimable value in compost and liquid manures as well as compost ingredients.

Using Compost

As referred to earlier, compost can be used when the original ingredients are only just barely recognisable. Compost at this stage is far from fully humified, and the nitrogen content is still susceptible to leaching by rainfall and irrigation. Consequently, it is best used on crops that are greedy feeders, such as corn, the cabbage tribe, pumpkins, lettuce and potatoes. As compost matures, it turns into a black, colloidal material in which none of the original components are recognisable. This material will last longer in the soil and is required for seed-raising mixtures.

In practice, we all use some compost before full maturity, even though we might prefer not to. The amount required depends very much on the fertility of the soil, its type and the crop. Light, sandy soils require heavier and more frequent additions of compost than heavier soils. Some crops abhor fresh compost, particularly carrots which fork. Peas and beans require little if any compost in the average garden; they are usually more than happy with what's left over from the preceding crop. Onions, like carrots, peas and beans, prefer to subsist on the compost residues from a previous crop.

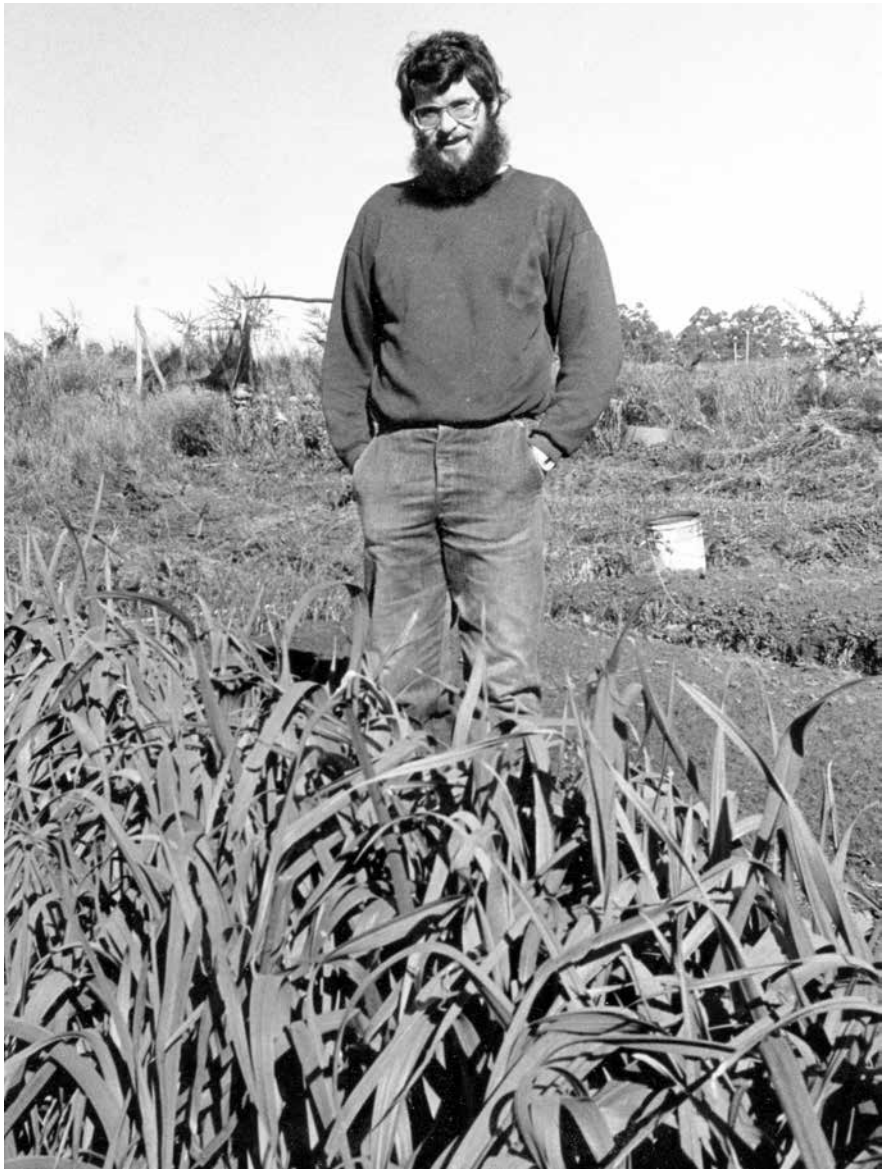
A reasonably fertile loam to heavy soil will need about 25mm (1") of compost preceding a heavy feeder. This amount can be increased with benefit; there is none of the toxicity problem with overfeeding that can occur with artificial fertilisers. Availability is more of a factor than overfeeding when using compost. Compost is unique in that it allows plants to consume nutrients as they are needed and usually at the rate they require.

Compost consists of living organisms, mostly microbes that are readily killed by sunlight. Consequently, it is somewhat wasteful to use compost as mulch. It is best lightly tilled into the top 80–100mm (3–4") of soil for its optimum benefit to be realised.

Gardeners are — let's face it — control freaks. Who else would willingly spend his leisure hours wresting weeds out of the ground, blithely making life or death decisions about living beings, moving earth from here to there, changing the course of waterways? The more one thinks about it, the odder it seems; this compulsion to remake a little corner of the planet according to some plan or vision.

—Abby Adams

The author in his market garden in 1987. The crop in the foreground is leeks.
Photo courtesy *Tasmanian Country*.



If you have built castles in the air, your work need not be lost; that is where they should be. Now put the foundations under them.
—Henry David Thoreau