EARTH FRIENDLY FOOD GROWING

How to develop a food growing practice that supports the Earth

Priya Vincent

WITH HEARTFELT THANKS AND GRATITUDE

To everyone who walks with me on this food growing adventure
in India and Malaysia and wherever else the Earth calls me.

To the land of Buddha Garden in Auroville
which led me to what I needed to see both

Within and without

They may turn you into a car park

but your teaching will not be lost.

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DEDICATION

This book is dedicated to the Earth that sustains us

and future generations of sustainable food growers

who will ensure that the Earth is able

to go on doing so.

INTRODUCTION

This book is about what I call ‘Earth friendly food growing’, the farming practice that has evolved in Buddha Garden over the last 24 years. Which is based on the way we connect and work with the Earth as we grow food.

During the twenty three years I have lived and worked in Buddha Garden community Farm in Auroville, many people have come to the farm wanting to learn about ways of food growing that give us healthy food without harming the Earth. They come often wanting to learn about our farming techniques and sometimes looking for a food growing system that they can use at home. While we are happy to show them what we do, techniques and systems are often of limited use to them unless they are growing food in the same kind of climate. This book does not therefore focus on techniques, (although there is information about techniques that you might find useful) but about the deeper questions of how, as we grow food, we develop our understanding and consciousness of natural processes so in a way that does not harm the Earth on which our food-growing depends. It is this approach which has, over time, evolved into our practice of Earth-friendly food growing that we use in Buddha Garden and other farms that ask for our help.

The fragility of many of our food systems has been highlighted by the recent Covid-19 pandemic As the pandemic has unfolded in the world it has brought to our attention the many unsustainable ways of growing food - ways which depend on the exploitation of natural resources and people and add to the present climate emergency. It has made many more people aware of just how dysfunctional some food systems are especially when they deliver food that is too expensive or lacking in nutrients for a large proportion of the population it serves. It is clear that other ways of growing food need to be found that sustain rather than deplete the Earth and that food systems must change to better serve people with more nutritious food that everyone can afford. More people practising Earth friendly food growing is a first step towards a more equitable food system that provides healthy food for everyone.

This aim of this book is to provide you with a basic understanding of this food-growing approach and the tools you need to develop a similar food growing practice of your own. Everything that we need to grow food comes from the Earth. In Buddha Garden we call these things ‘the six elements of Food Growing’. These are the soil, microbes, water, plants, insects and animals which together with sunlight are the basis of the food-growing process everywhere. A lot of this book is about these elements and how to work with them so that, rather than depleting them as often happens with modern industrial farming, we can instead sustain them. The first step is to understand the elements of food growing and the principles of how to work with them in a way that does not deplete or destroy them. Then they will continue to support your food-growing process indefinitely.

The next and more profound step of the practice is to start growing your own food. This is the stage at which you will have the opportunity to bring together the elements of food growing in your own special way in your own place. This is an ongoing process of endless learning during which you will develop what I call an ‘inner sun’ – the sum total of your learning, understanding, experience and awareness – of what is necessary to grow healthy food where you are. Working under the outer sun you will develop your own practice of Earth-friendly food growing which is right for you and your place.

In this evolving practice we can start growing our own food or support others who do so in a way that nourishes both the Earth and ourselves. In doing this we help to support the Earth so the Earth can go on supporting us.

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THEN

THEN – A short history of farming and the modern organic farming movement

Farming, the human engagement with earth to produce the sustenance needed for human life to continue, is a relatively recent phenomenon. This began 12,000 years ago when small hunter/gatherer societies started to settle and grow some of their food. These small semi-nomadic groups, probably comprising no more than 20–30 people, paved the way for the domestication of plants and animals, which is the defining characteristic of agricultural societies. Domestication can be characterized as the human modification of plants and animals and involves genetic change through conscious or unconscious human selection. This domestication was preceded and made possible by the accumulated human experience, over millennia, of wild plants and animals and the trial-and-error experimentation of the hunter/gatherers.

There was probably a gradual shift towards cultivation with continued reliance on hunting and gathering. It is thought that reliance on agriculture as the main source of food may have come about when the population of a given region could not be solely supported by hunting and gathering. The advantage of agriculture over hunting and gathering was that it increased food production per unit area, making it easier to feed a population from the same amount of land around a settlement.

The stages of the crop cycle – planting, harvesting, and storing – imposed various artificial selection pressures on the plants used. These included harvesting only those plants with preferred characteristics such as a certain taste or those which could be stored more successfully. Over time, this produced changes in the crop and seeds that are characteristic of domesticated crops. These changes (referred to as domestication markers) are most pronounced when comparisons are made between the domesticated crop and its wild relatives. At the same time the benefits of animal domestication were becoming evident. This included being able to use the animal for transport, farm work such as ploughing, and for food. Animals also provided other items like wool for clothing and dung that was dried and used as fuel. It was also put on the land to improve its fertility. As farming developed so did the capacity of the land to produce food, enabling larger sedentary communities to evolve. It is highly ironical that while population pressures have led to more efficient farming practices, these in their turn have invariably led to greater population increases. Until now, when the limits of global food production for the global population are evident.

FARMING METHODS

From the very beginning, human beings created a range of methodologies that allowed improving food production techniques to be used. There was no single technology, but an array of strategies depending on the resources available and the climate. Agriculture in temperate climates was seasonal and seed-based. Cereals were grown by scattering seed across ploughed fields. Vegetables, legumes and corn, on the other hand, were planted from seed in rows either in separate holes or in furrows. Agriculture in the humid tropics mimicked the forest. Crops came from perennial (i.e. the same plants continuing year after year) plants that were productive over the entire year and found in polycultures, which were a large number of different plants growing together as in a forest.

Perhaps the most significant technological development in farming was the plough. Instead of having to laboriously make holes for seeds by hand, or sowing seeds on bare ground, it was possible to plant in rows or furrows. This made farming more efficient, allowing more crops to be planted in less time and more food to be produced. The first plough, created in Mesopotamia, was a wooden device with a stone or bone protrusion to make furrows in the soil. Eventually a ploughshare, or a blade made of metal, was developed, and this increased the plough's efficiency.

Fallowing was an important technology perfected in the Middle Ages as part of a crop rotation pattern that made agriculture more sustainable. In this method, a legume – a plant able to take nitrogen from the air and 'fix' it in the soil – is planted in the first year. This enriches the soil with nitrogen, which feeds the cereal crop that is planted in the following year. In the third year the land is left uncultivated, or fallow, in order for it to regain soil moisture and restore soil health. This pattern approximates a natural ecosystem and is more sustainable over the long term than continuous cropping, as it enables the soil to be progressively renewed.

The fallow crop-rotation system maximized food production, but it could not accommodate an increasing human population. By 1650 the world population had reached a half billion, and half of these people were in settled urbanized villages, towns and cities where they were not engaged in agriculture. At this point in time all the major food crops and domestic farm animals known today were already discovered and used worldwide. The only significant crops added since 1650 are industrial crops such as rubber.

From the mid-seventeenth to mid-nineteenth century agricultural outputs increased with new rotations with leguminous and root crops. Increasingly, agriculture practices became more scientific, and the use of machines and fossil fuels enabled increased yields and labour productivity. Towards the end of this period there was increased transfer of crops and livestock from the lands of their origin to other parts of the world.

MODERN FARMING

During the latter half of the twentieth century, what is known today as 'modern' or 'industrial' agriculture was very successful in meeting a growing demand for food by the world's population. Yields of primary crops such as rice and wheat increased dramatically, the price of food declined, the rate of increase in crop yields generally kept pace with population growth. This boost in food production was mainly due to scientific advances and new technologies, including the development of new crop varieties, the use of pesticides and fertilizers, and the construction of large irrigation systems.

Modern agricultural systems have been developed with two related goals in mind:

to obtain the highest yields possible

to get the highest economic profit possible.

In pursuit of these goals, six basic practices have come to form the backbone of modern food production:

Intensive tillage, where the soil is tilled/ploughed deeply with the use of machines. The soil is loosened, water drains better, roots grow faster, and seeds can be planted more easily. Cultivation is also used to control weeds and work dead plant matter into the soil.

Monoculture, where one crop is grown alone in a (sometimes very large) field. Monoculture makes it easier to plough, sow seed, control weeds, and harvest as well as expand the size of the farm operation, and have lower unit costs which improve profitability.

Application of inorganic fertilizer, where very dramatic yield increases occur with the application of synthetic chemical fertilizers. Relatively easy to manufacture or mine, transport, and apply, fertilizer use has increased from five to ten times what it was at the end of World War II (1939-45). Applied in either liquid or granular form, fertilizers can supply crops with readily available and uniform amounts of essential nutrients to promote plant growth.

Irrigation, where food supply receives a great boost either by supplying water to crops during times of dry weather or in places of the world where natural rainfall is not sufficient for growing most crops. Drawing water from underground wells, damming or diverting rivers, and building reservoirs and distribution canals have improved yields and increased the area of available farm land.

Chemical pest control, where synthetic chemicals are an effective and relatively easy way to limit the spread of pests and weeds. Chemical sprays can quickly respond to pest outbreaks.

Genetic manipulation of crop plants, where use of hybrid and genetically-modified seeds has led to higher production and easier farming.

Each practice is used for its individual contribution to productivity, but when they are all combined in a farming system, each depends on the others and reinforces the need for using the others.

Modern agriculture is sometimes called 'agribusiness,' because using these techniques has increased the average yield of all plants and productivity per unit area up to 50%, making agriculture a profitable business. During the last fifty years, worldwide, the number of farms has decreased while the size of farms has increased.

But for all the benefits of modern agriculture there are also problems, which include:

Soil degradation because of excessive tilling and use of chemical fertilizers, which do not put organic matter in the soil. With no organic matter to renew its composition, the soil becomes like dust and is more liable to be blown away by the wind. This is particularly the case in tropical areas where the soil is generally more fragile.

Chemical pollution of the environment from the use of chemicals for pest control and inorganic fertilizers. Large monocultures are prone to pest outbreaks requiring the continued and excessive use of chemicals, which can then spread and poison the entire region.

Shortage of water due to large-scale irrigation from underground water, streams and lakes has led to more water being used than can be naturally replenished through rainfall.

As farm output has increased, so has the world's population. Since the middle of the nineteenth century the population has increased from one billion to six billion – an increase that would not have been possible without increases in agricultural yields. At present humans produce and consume over a twenty-year period as much food as was produced in the eight thousand years between the development of agriculture and the sixteenth century. Given the pressing need for a successful food production system to feed this population, there are fears that a failure of one of the crucial links in the agribusiness model could undermine the whole system. A water supply that becomes too polluted or scarce, or pests which cannot be controlled by chemicals, are both factors that could undermine the entire scheme and lead to mass starvation.

This process of land degradation resulting from industrial farming methods was all too apparent on the Buddha Garden land when I first arrived there in 2000. Earth bunds, falling into disrepair, were still visible around small fields, but the soil looked eroded and was home to only a few rather sickly-looking eucalyptus trees. The land was no different from the barren plateau on which Auroville was founded in 1968, about four decades before I moved to Buddha Garden.

Yet, only two hundred years ago, this eroded land was covered by a jungle known as 'tropical dry evergreen forest'. This consisted of an uninterrupted mass of green, three to four metres high, interspersed with small trees that never formed a closed canopy. It contained a very wide variety of shrubs, vines and lianas and could be so dense that it was impossible to penetrate. A stone artifact discovered in the area, dating from 1750, describes the exploits of a local king hunting for elephants and tigers in this forest.

In 1825, in a bid to drive away the tigers, the first trees were felled in an area close to Pondicherry (now Puducherry), a town about 8 kms south of Auroville. In the following years the forests were periodically cut down to provide wood for export, as well as to build the growing cities of Puducherry and Kalapet. The British accelerated the process of forest destruction by allocating plots of land to anyone who would clear it and cultivate it for a year. Individuals who took up such allocations would often do so just for the first harvest, after which much of the land was left fallow. The last remaining plots of forest in the Auroville area – two thousand neem trees – were cut down in the mid-fifties to make boats.

In less than two hundred years, what had once been green and fertile was turned into an expanse of baked red earth scarred with gullies and ravines. Each year tons of topsoil, whatever of it remained, was swept into the sea, turning it red. What was once a heavily forested and fruitful land had become an untillable red clay desert on which the Tamil villagers tried, with increasing desperation, to grow food.

A local person told me that when he was a child, he had helped with the rice cultivation that once took place on what is now the Buddha Garden land. He described the work he had undertaken when young, but that as he grew up this work had been discontinued, and he had turned to carpentry as a way of making a living. He said that the climate had become too unpredictable and the soil too poor for him to continue farming. He told me he was unsure why this had happened. To get rid of pests they had used 'white powder' which was probably DDT. Maybe it was this and the use of fertilizers that adversely affected the soil and led to a reduction in crop production.

At the same time as agricultural production was falling, the surrounding area became more urbanized. More and more people preferred to work for money to buy food rather than grow it for themselves. With the growing unavailability of labour and the difficulty of obtaining sufficient yields, those who still had land planted cashews on the more arable land and eucalyptus trees where nothing else would grow. Neither of these had to be protected from animals and needed little attention except at certain times of the year. It was possible to farm these crops while working at a job. Though cashews were a very valuable cash crop, the cashew trees had to be heavily sprayed with pesticides, which eventually poisoned the soil as well as bringing illness to those doing the spraying. Where eucalyptus trees were planted these sucked out whatever nutrients were left in the soil.

Despite this unpromising situation, with hard work it has been possible to change this state of affairs. I have found that bringing the land back to life and productivity has been one of the most deeply satisfying experiences of my life.

THE MODERN ORGANIC FARMING MOVEMENT

A response to the seeming un-sustainability of modern farming was the rise of modern organic farming, which began in the early part of the twentieth century. In England, in the 1920s, a few individuals in agriculture began to speak out against the trend of turning agriculture into 'agribusiness'. The British botanist Sir Albert Howard is often referred to as the father of modern organic farming, although he obtained his ideas from the traditional farming practices used in India, which he regarded as being superior to modern methods. His book, An Agricultural Testament, influenced many scientists and farmers of the day and continues to do so, including me. In Germany, at about the same time, Rudolf Steiner was developing his principles of biodynamic agriculture. In the early 1900s, an American agronomist called F.H.King toured south-east Asia and published his findings about sustainable practices he had observed in this region called the Farmers of Forty Centuries. This eventually became an important organic farming reference.

In England, in 1939, the first scientific comparison of organic and conventional farming was carried out by Lady Eve Balfour, the results of which were published as The Living Soil and which led to the setting up of the Soil Association in the UK. In Japan, Masanobu Fukuoka, a microbiologist, began to doubt the modern agricultural movement, and in the early 1940s returned to his family farm to develop the 'no till' or 'natural' method of organic farming.

In 1962, Rachael Carson, a prominent scientist and naturalist, published Silent Spring, which chronicled the terrible effects of DDT and other pesticides on the environment. This book is widely considered as being the key factor in the banning of DDT by the US in 1972. The book and its author are also often credited for the launching of the worldwide environmental movement.

In 1972, the International Federation of Organic Agriculture Movements (IFOAM) was set up in France. IFOAM aimed at meeting what the founders saw as a major need for the organic movement – the diffusion and exchange of information on the principles and practices of organic agriculture across national and linguistic boundaries. The Federation included developing countries, which were at the time experiencing the first effects of the 'green revolution,' a concept based entirely on chemical farming methods. IFOAM was supposed to act as a much-needed counter point to what was already being perceived as the disastrous impact of "chemically-based" agriculture on the environment and peasant societies in the developing world. The Federation also had the task to show the global relevance of organic agriculture as part of a viable solution to world hunger.

Globally, in the 1980s, various farming and consumer groups began seriously lobbying for government regulation of organic production. This led to legislation and certification standards being enacted, starting in 1990s and continuing to date. Since the early 1990s, the retail market for organic farming in developed economies has been growing by about 20% annually due to increasing consumer demand. Concern for the quality and safety of food and concern for the environmental damage arising from conventional agriculture both seem to be equally responsible for this trend.

EATING, FARMING AND THE ENVIRONMENT

Another more recent debate focuses on the changes in human diet and how this impacts the environment. What we eat has changed considerably since humans first made an appearance on Earth. There was a popular idea put forward at the beginning of the twentieth century, that the diet of the first humans consisted almost exclusively of meat. It was this, according to some scientists, which enabled humans to develop the larger brain that underpins the ongoing development of humans to this day.

With the evolution of agriculture the human diet changed drastically. Instead of having to go and catch meat, humans started eating a range of domesticated grains, which provided a predictable food supply. This enabled a higher birth rate among the settlers than hunter-gatherers. Was this diet based on agriculture better for humans or not?

It seems that the earliest farmers ate a less nutritionally diverse diet than those of hunter-gatherer groups. This diet gave the farmers teeth cavities and other similar problems that are rarely seen in the dentition of hunter-gatherers. As animals were domesticated and served as a source of food, they were also a source of parasites and new infectious diseases. Farmers also suffered from iron deficiency, shrank in stature, and experienced more developmental delays. Although it boosted population numbers, early farmers' diet and lifestyles were clearly not as healthy as those of hunter-gatherers.

Looking at modern-day indigenous hunter-gatherer societies, it is observed that although meat is valued as a food more than any other, in most cases only about 30% of the diet consists of meat. Only a few groups of Inuit get the majority of their calories from meat. And there are likely to be sometimes quite long periods when much less meat than this is eaten. It seems that although hunter-gatherer societies crave meat, what they actually eat and what accounts for the better part of their diet is more likely to be food that has been foraged. This includes a wide range of tubers, nuts, plantains, manioc etc. In many societies, most of the foraging is carried out by women.

Humans vary in their ability to digest certain foods. Originally humans were unable to digest the milk of another animal, but when cattle began to be domesticated 10,000 years ago some groups over time developed the capacity to do this. Humans also vary in their ability to extract sugars from starchy foods. Populations that traditionally eat more starchy foods have different genes from groups that traditionally eat more meat. There is in fact a tremendous variation in what foods humans can thrive on, depending on genetic inheritance, which itself has been affected by the food available in the area where they live. Perhaps what makes us human is the ability to adapt to many different habitats and create many healthy diets. Although unfortunately the modern western diet, reliant on processed food, doesn't appear to be one of them.

As cities have grown and incomes have risen around the world more and more people have left traditional diets behind to eat a more westernized diet that includes refined sugars, fats, oil, the three major staples – rice, wheat, and corn – and land-intense agricultural products like beef. These dietary shifts are thought to be responsible for the increased incidence of type 2 diabetes, coronary heart disease, some cancers and other chronic diseases. High meat consumption and high fat vegetarian diets were thought to require more land resources than other food choices such as the vegan diet. Now it appears that the link is much less strong and a lot depends on how the food is being produced. Some vegetable-based foods take as much energy and other environmental resources like water as some meat-based products. A lot depends on where and how the food is being produced. Lettuce grown in season takes much less resources than lettuce grown in hot houses all year round. Or, when it is shipped all over the world, from places where it grows easily.

It is clear that there are many complex connections between our modern western diet, human health, and the degradation of our earthly environment. It is also clear that there is no one diet which will both 'save' the environment and improve human health, although there are a range of options that would be better than the modern westernized diet and industrial-type farming. In this situation the best we can do is to make the most conscious choices we can. This being based on the evolving knowledge we have about our health, the health of the earth, and the social and economic environment in which we find ourselves. Eating is our strongest link with the earth that sustains us. The choices we make about what we eat can make a difference in many ways.

WHAT IS THE FUTURE FOR ORGANIC FARMING?

The sales of organic food in developed countries have grown at a tremendous rate in recent years, and with it the area of land now being used for organic farming. The global organic farming market is expected to exhibit a growth rate of 8.4% from 2018 to 2026. Despite this, the global area of land under organic farming remains very small at 1.2% of the total agricultural land. India has the largest number of organic producers in the world, and is home to 30% of the total number of organic producers worldwide. Australia has the largest current area of land under organic cultivation, followed by Argentina and China. It seems that there is increasing interest in organic farming, and the market continues to grow, but how does this affect farmers?

Making the transition to organic farming isn't necessarily easy. Farmers must learn a new set of skills; yields will almost certainly suffer in the first few years; and there is a three-to-five year transition period before products can be certified as organic. These challenges can create financial insecurity. Growers may also have difficulty acquiring reliable information on organic farming. For example, there is only minimal information available on production costs, which is essential knowledge for making farm management decisions. After transition, however, direct sales of local organic produce may return up to 80 cents of each food dollar directly to the farmer, which compares favourably with the 19 cents received on average by conventional farmers trading bulk commodities. In India, it can be very difficult for small farmers working with tiny profit margins to make this transition, especially when there is no well-defined market or easy access to markets for organic produce where they can hope to receive the 'organic premium' and thus more money for their produce.

Initially, organic farming was carried out mainly by small farmers who sold their produce locally. Given the increasing demand for organic food in developed countries, however, it is not surprising that large corporations have entered the organic market. Two US organic and natural food retail chains – Wild Oats and Whole Foods Markets – have over 200 outlets and sales of around one billion US dollars annually. Food industry giants such as General Mills, Gerber, Heinz, Dole, Kellogg's, Mars, ConAgra and ADM are all marketing organic food brands. General Mills now owns leading organic manufacturers Cascadian Farms and Muir Glen. Heinz has developed organic ketchup, Wal-Mart (a large American supermarket) stocks organic foods. People are even eating organic TV dinners. More organic foods are accessible to more people than at any time since the start of the industrial food era. Is this progress? Or will it drive down prices, squeeze out the smaller farms, and lead to greater social injustice?

The successful entry of large companies into the organic market is raising some difficult questions about the key values and vision for sustainable agriculture. On the one hand, it is good that organic foods have achieved such wide appeal, for as some people argue that without the support of supermarkets organic food will never develop the political clout needed to shift government policy on food production in the direction of sustainability. On the other hand, some worry that the vision of the early organic farming activists – who sought not only healthier food and more environmentally-friendly production but also smaller and locally-based alternatives to the dominant food system – is being lost in the rush to maximize market share. These critics point out that the current expansion of organic food includes sourcing cheap raw materials from developing countries, and thus reproducing the neo-colonial structure of the conventional food system. There is also the problem that when organic food becomes just another possibility in the choice that supermarkets have to offer, consumers may cease to think critically about the agribusiness and all that it implies in terms of social and environmental justice. Supermarket organics may allow shoppers to assume they can eat healthier and be greener without changing, or inconveniencing, the consumer lifestyle.

The range of opinion in the organic movement, however, is diverse, and many believe that organic food can be defined broadly enough to include a wide variety of practices and values. There is also a feeling, however, especially in America, that the organic certification process has been developed with an eye to the needs of agribusiness rather than the needs of the Earth for sustainability. Others feel that the main aim is to produce good quality food in a range of different ways that enables everyone to participate and is affordable for all. One of the arguments against organic food has been that it is elitist and can only be afforded by the well-off.

To preserve the original values of organic food production it is felt that certification needs to be changed to include the wider ecological issues. Certification should include a 'proximity principle' in their standards which would strengthen support for local economies and reduce the energy-intensive transportation and packaging. Food grown by an organic farmer and sold at a local farmers' market, at the farm gate, or to local restaurants, uses a comparatively small amount of fossil fuel from transportation, refrigeration and packaging. This is not the case for, say, organic Hawaiian papayas refrigerated and shipped to New York in mid-winter, or for organic TV dinners, whose certified organic ingredients may be grown in several different countries.

Some feel that standards for enhancing biodiversity should also be included in the certification process. A 100-acre organic monocrop planted with a single variety of vegetable and picked by migrant workers hardly fits with a larger organic agriculture vision of ecologically sustainable and socially responsible farming. The challenge is how to reconcile organic agriculture's emphasis on biodiversity, and small-scale production with a corporation's emphasis on uniformity and mass-marketing. The International Federation of Organic Movements (IFOM) recently requested proposals to develop biodiversity standards for organic production, and has already been working internationally with the International Union for the Conservation of Nature for several years on these issues.

Neglect of these core environmental principles is leading to questioning of the entire certification system. In many countries, some farmers are letting go of the word "organic" and forgoing the certification process (which can be very expensive), and primarily selling their produce at local farmers' markets – so called Community Supported Agriculture (CSA). This is an attempt to create both a market for themselves and bring together people who not only want to eat organic but want to have some connection with the place that produces their food.

This model of local agriculture started 30 years ago in Japan, where a women's neighbourhood group, concerned about the methods used to produce their food initiated a direct growing and purchasing relationship between themselves and local farms. This arrangement, called 'teikei' in Japanese, translates to "putting the farmers' face on food". CSA also evolved in Europe and in California, USA, in the 1960s, stimulated by the rapid industrialisation of food production, and where consumers felt increasingly detached from the sources of their food. Fundamental to CSA is an understanding of mutual support between the farmer and those that consume their produce, often with some degree of commitment. For example, a vegetable grower may draw up a budget reflecting the production costs for the year, and community members sign up and purchase their shares either in a lump sum or instalments. In return for their investment, members may receive a box of fresh, locally grown food every week.

CSAs reflect the culture of the communities they serve, the capabilities of the CSA land, and the farmers who manage it. Therefore, no two CSAs are the same, as they are context-specific to local communities and tend to change with the community's needs over time. They can include:

customer-supported box schemes

conservation based initiatives

intentional communities; rent/adopt schemes

urban food growing projects

community allotments

charitable projects.

All of the above initiatives have some form of direct public participation. CSA is therefore not a model to be simply replicated; it is about how to achieve a new local food system. For the consumer it is an opportunity to directly influence how food is produced and the environment managed.

However it is organised, CSA gives farmers and growers the fairest return on their products. They receive a guaranteed market for their produce, and can invest their time on growing the food rather than looking for customers. As with all types of local food initiatives, the local economy is stimulated by consumers supporting local business. The grower is part of a community and is no longer isolated. Consumers benefit enormously by receiving fresh, locally grown produce on a regular basis. Education about where food comes from and how it is produced is also a strong feature of these schemes. Most CSA schemes welcome members to visit the farms on open days, and even help with the harvest. As CSA farms are directly accountable to their consumer members, they strive to provide fresh, high-quality food, typically using organic or biodynamic farming methods. These changes are driven in part by farmers' beliefs that the term "organic" has been devalued by the entry of corporate players. But additional motivations behind the growing trends toward CSA include a desire for more intimate trading relationships with customers and inhibitive costs of certification.

The concerns and values that triggered the development of organic agriculture in the first place are clearly being tested by its seeming success. That original vision saw success not only as commercial expansion, but as the expansion of a civic dialogue focused on bringing sustainability and social justice to the food system. It is a vision characterized by a caring and just relationship to the local landscape, and to human beings. Unless this wider vision is expressed in practical ways, organic food becomes just another consumer choice based on unsustainable ecological and economic practices, like the ordinary food market.

NOW AND FOREVER

HOW CAN WE GROW HEALTHY FOOD WITHOUT PLUNDERING THE EARTH?

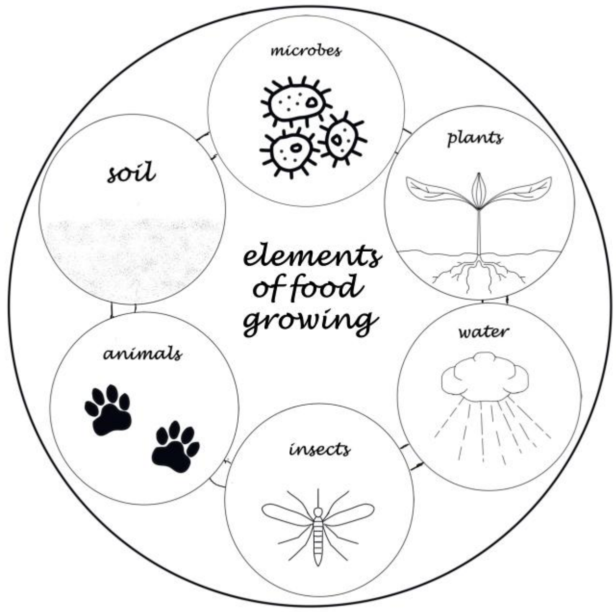
Throughout history humans have frequently farmed in unsustainable ways. There are many examples of civilizations that have died and land abandoned because the fertility of the soil had diminished to the extent that it could not support humans any more. Modern industrial farming methods have merely intensified and continued on a larger scale what has already been in existence for many years. When the population of the world was much less, it was easier for societies to migrate elsewhere and find new places in which to grow food. With the presents level of world population this option is no longer open to us, and hence the pressing need for the wide adoption of farming methods, which will not lay waste the earth on which our food depends. There are also, of course, examples of civilizations that have lived for thousands of years in the same place and have found ways to continuously regenerate the earth on which they depend.

In setting up Buddha Garden, I saw myself as playing a small part in this movement of earth restoration by bringing the land back to life and growing food for the community. In the twenty three years of Buddha Garden's existence, I have had much opportunity to reflect on what I am doing, since I am often asked to describe and define my method of food growing. This has turned out to be much harder than it sounds.

I farm in the tropical climate of south India and the techniques I use here are either not universally applicable or need to be modified if they are to be useful in another place and climate. The techniques I use have also changed over the time I have been here. New ways of doing things present themselves, and there is a need to tackle different kinds of tasks as the farm evolves. I am also not an exponent of any well-known organic farming method, such as 'biodynamics', 'natural farming' or 'permaculture'. Although over the years I have used and continue to use various practices from these different approaches. Calling myself an 'organic farmer' is also questionable. Buddha Garden has only very recently become officially registered as an organic farm, along with a group of other Auroville farmers. But given the debate over what 'organic' really means, the different standards of different organic certification organisations, and even whether it means anything at all, defining what we do in terms of this is not particularly helpful.

The essence of our approach to growing food in Buddha Garden is not based on a set of techniques, a particular philosophy of farming, or an external certification process. It is based on a specific kind of engagement with the earth and its natural rhythms. Perhaps it is better to describe what we do as a 'farming practice' or approach rather than a 'farming method' consisting of a list of different techniques. It is also something which has evolved over time due to our evolving knowledge and new developments, but also due to team member's relationship to Buddha Garden, each other, and what we do to grow food. We all share the same values when it comes to how we grow food, but our approaches and processes can be different. This can make it quite difficult for some of our volunteers who come wanting to learn techniques, and then finding that there are several ways of doing things in the same place!

In plotting the essentials of this practice, I have developed a conceptual map which I call the roots of our farming practice. Firstly, we consider the basic things from the earth that have to be brought together to grow food. These are the soil, microbes, water, plants, insects and animals which are needed and/or are a necessary element of the food production process.



Each of these elements is supported by nature and natural processes. To grow food in a way that does not take away from or harm these elements requires that we understand each element and the natural processes that support it. Then we are able to engage with each element in our day-to-day food growing activities in a way that sustains the natural processes that sustain that element and the natural world in general. I call this evolving ongoing process 'the light of evolving understanding'.

When we work with the elements of food growing we do so within the seasons of the year. A season is a division of the year marked by changes in weather, and the amount/intensity of daylight. In temperate and polar regions the seasons are defined by large changes in the intensity of sunlight that reaches the earth's surface. At different times of the year days can be very long or very short and temperatures in different seasons can vary considerably. In tropical and sub tropical areas there is less change in the length of days and intensity of sunlight. Here the seasons may be defined more by certain types of weather such as monsoon rain or very high temperatures. Throughout the world, local conditions such as height above sea level or proximity to the ocean can create local differences to the nature of the seasons.

Another way of looking at the seasons, and one that over the years I have tended to use more, is to experience a season as a period of the year when only certain types of plant and animal events happen. This will of course be determined by the temperature, light and general weather conditions of the place at the time. Everywhere certain plants grow better in certain seasons, and some animals will only reproduce at certain times of the year. Most places have an annual cycle of four seasons, but in some places, like India, traditionally there were six seasons and some indigenous communities have more than this.

Wherever we are growing food, we need to understand seasonal variations in that place and what grows well in the conditions of each season. Over a long period of time plants that grow in certain seasons have become adapted to those seasons. They are known as 'seasonal plants' and grow strong in the right seasonal conditions for them. Generally, these plants do not need extra food or water if they are grown in the right season. In these circumstances they do not usually suffer too much from insect pests and other diseases. Either they have learnt to repel the pests around at that time or the pests that might attack them are not very plentiful in that season. For these reasons these are good plants to grow for food.

Humans also adapt to the seasons, and at least some of the food grown in a season is traditionally thought to be good for human consumption in that season for different reasons. There may be a fruit or vegetable that will mitigate the worst of the seasons' effects like extreme heat or cold. Or, there maybe some other edible, locally grown product that bolsters the immune system against diseases seen in particular seasons. For this reason, many believe that it is best for humans to eat local food locally grown in season, as this is the food best adapted for their bodies to cope with the conditions of where they live.

NATURAL PROCESSES

For the industrial farmer, the elements of food growing – the soil, microbes, water, plants, insects and animals – are perceived only as inputs to be manipulated according to the farmer's desire to increase production and profits. Thus seeds are developed which maximize production, sometimes at the expense of taste and vitality. Where the soil is deemed insufficient, fertilizers and pesticides are used to stimulate plant growth and eradicate pests and weeds. In contrast, the sustainable farmer sees the food-growing elements as something to be preserved with the help of the natural cycles that support it. What are these natural cycles?

I see nature as the template for how we engage with the earth to grow food in Buddha Garden. We do not seek to copy nature exactly, but to make sure that we keep and strengthen those natural processes that support the overall health of the ecology of the farm and the food we grow there. By observing nature, we see that:

There is infinite variety both in the plant and animal world. Have you ever seen a monoculture in nature? Biodiversity includes the whole variety of life on Earth, which is made up of many thousands of different animals and plants. It also includes the genetic variation within species and the complex ecological systems to which they belong. There are many intricate relationships between species and habitats that we do not always fully understand. Even tiny or insignificant plants and other living beings may have a vital place in the food chain, or some other role to play within the whole network of living things. If one small part of this system is made extinct, much may be lost from disrupting one or more living cycles. We need to protect this diversity, because we and all other living things on Earth depend entirely on it. Within Buddha Garden we have found enhancing diversity of everything – microbes, insects, plants – has many benefits, from increasing the fertility of the soil to keeping certain pests in check.

There is constant transformation as nature renews itself constantly. Nothing is thrown away, nothing is discarded. Everything that is waste at one point of the process is transformed into something which can be used by something else. Human beings are the only part of the natural system who have ignored this reality and used nature as a dustbin for plastic and other substances that cannot be recycled by nature. Plastic may appear to disappear, but it either takes thousands of years to completely break down, or more likely does not break down but just breaks up into smaller and smaller pieces, which eventually pollute nature and eventually our bodies. Maybe, eventually, we will understand this, and create a system that transform plastic in the same way that nature transforms all the waste products created by the natural world.

There is constant adaptation, which we have seen a lot in Buddha Garden. Different plants thrive in different parts of Buddha Garden, as the conditions are different on different parts of the land. The seeds we collect and vegetables we grow have all, over time, adapted to the Buddha Garden climate. Pumpkins, which were eaten completely by bugs when I first came to Buddha Garden, now happily co-exist with the bugs. As the climate changes, we expect that the plants we grow will also change and adapt to continue to provide us with food.

In our day-to-day activities, as we work with the elements of food growing, we try to engage with them in a way that bolsters these natural cycles. This in turn continues to renew the elements of food growing. This is particularly important when we are faced with things like pest attacks or lack of water that hamper our food growing efforts. Any action we take has to both deal with the problem and support the natural processes. This is why it is important to understand each of the elements and the natural processes that support them.

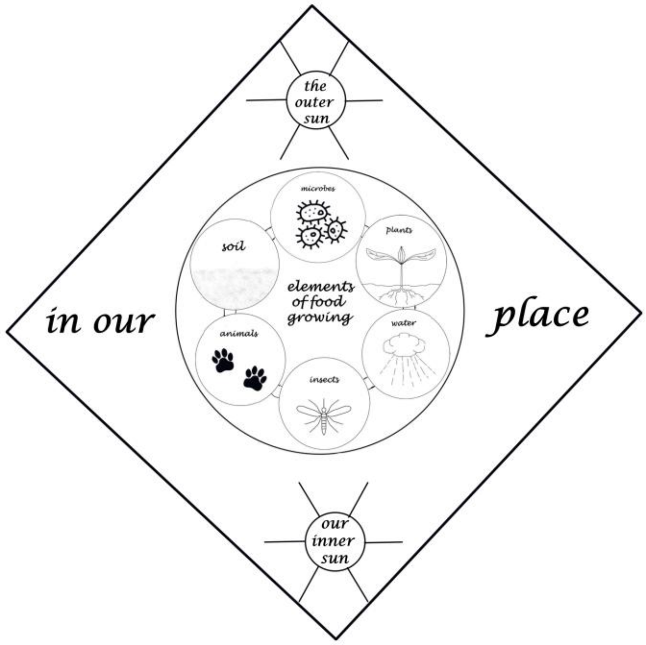
BRINGING IT ALL TOGETHER

The way in which these elements are brought together into an interlocking whole depends on the creative vision of the grower. This will include the practical needs of the food grower, for such things as food and income, and might also embrace a particular philosophical or spiritual focus. At the same time the food grower has to be alive to the properties of the place where the food is being grown, the characteristics of which might limit or modify the original creative vision. These limitations vary according to different climatic areas as well as the physical characteristics of the land. It also includes the human resources that are available, which includes cooperation with other food growers as well as possibly drawing help and support from the community for whom the food is being grown.

Given the infinite variety of the people and places the way in which this evolves is very individual. There is not a mechanical way of implementing this kind of practice, as no two people would grow food in exactly the same way. If someone else had come to the land of Buddha Garden it would be a very different place to what it is now. Although every individual would have to work with the same physical characteristics of the place and seasonal variations, what would eventually evolve would be very different. It is in Buddha Garden we strive to bring together the elements of food growing, natural processes, and our creative vision, to forge a supportive and sustainable whole that enables food to be grown. Food that is healthy both for us, our community and the Earth.

To develop a food-growing practice like this in a particular place the food grower needs to understand all the food-growing elements – about the role of each element in the food-growing process and how each is supported by nature. This inner illumination and understanding is what the rest of this book is about, aiming to help you make the first step towards doing this. The next six sections in this book will provide you with a basic understanding of each element and the best way to engage with it to grow food. With this understanding, you will be ready to bring your own vision to the place where you grow your own food. It will be up to you to decide the best way of bringing the elements of food growing together in your place, and how to forge them into a functioning whole.

The next step and the greatest learning will be in the practical process of growing food. There will always be more to learn – from books, internet, teachers and other farmers – but the greatest teacher will always be your place and the nature that surrounds it. Watch and see how your place responds to your activities. Enjoy the journey of seeing how you and your vision co-evolves with nature.


the outer sun
in our
place
microbes
plants
soil
elements of food growing
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our inner sun

SECTION TWO

WORKING WITH THE ELEMENTS OF FOOD GROWING

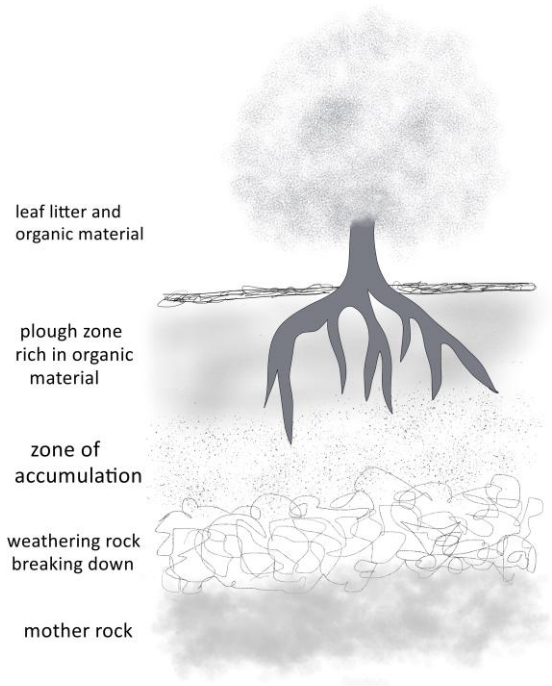
Many volunteers coming to Buddha Garden talk about 'wanting to work with the soil' or 'wanting to feel their hands in the soil.' They feel a strong need to make a connection with the soil, even though they have never done this type of work before, or have lived in cities and have never had much opportunity to be close to nature. Inevitably, some come with somewhat romantic notions of what this work entails, and find it difficult when confronted with heavy digging, squelchy mud, hot sun, and dust. Even so, Despite the difficulties it seems to me as if the soil is calling them. As if on some level they recognize how intimately we are connected with and depend on the soil, and therefore its importance to us. Maybe they also sense the satisfaction to be gained from working with the soil to produce our most basic need – food.

In Buddha Garden, being part of the process that has brought eroded and inadequate soil back to life has been one of the most deeply satisfying things I have ever experienced. I have greatly appreciated the opportunity of watching the dramatic improvements in the food we have grown as the soil has improved. Since the quality of food, its taste, texture and nutritional value is dependent on soil quality, much of what we do still involves working with the soil. For me, so-called 'soil improvement' is an ongoing process. It is perhaps better described as 'soil/fertility maintenance,' and doing this is one of the most important things we do to produce good and healthy food in Buddha Garden.

SOIL DEVELOPMENT

Soil forms itself extremely slowly with top soil being produced naturally at a rate of 1mm in 200-400 years. It takes 2,000–10,000 years for a full soil profile to emerge, a period which is exceedingly long in human terms, but comparatively short in the total history of the earth.

A cross-section of soil shows five layers, each with different characteristics. The top layer (called the O-horizon) is composed of decomposing organic material, leaf litter and organic material. The layer below that (A-horizon), called the plough zone, is where most plant roots are found together with soil bacteria. The next layer (B-horizon) is where nutrients from below and those leached from above accumulate and is called the zone of accumulation. Below that (the C-horizon) is where the soil is weathering from the bottom layer (R-horizon), which is the parent rock from which the soil is formed. The following diagram shows this process.



Soil has both biological and chemical constituents, the latter being derived from rock.

The first process in the formation of soil is the weathering process whereby under the influence of ice, heat, wind and rain, rock is shattered into smaller pieces. As the weathering process continues, the rocks break down into:

Minerals in solution (the basis of plant nutrition)

Oxides of iron and alumina

Silica and very fine silt consisting mainly of fine quartz and sand

Depending on temperature and rainfall, new minerals are formed from these elements. The most important of these are oxides of iron and alumina, which combine with silica to form clay.

In **temperate regions** a so-called 'three-layer clay' is formed, the surface of which is able to bind and retain minerals and nutrients. This type of soil is nutrient-rich and able to absorb large amounts of water.

In **hot and humid tropical regions** 'two-layer clays' are formed producing arable but easily dried soils. These clays are not able to hold much water, or nutrients, and are thus more fragile than the clay soil in temperate regions.

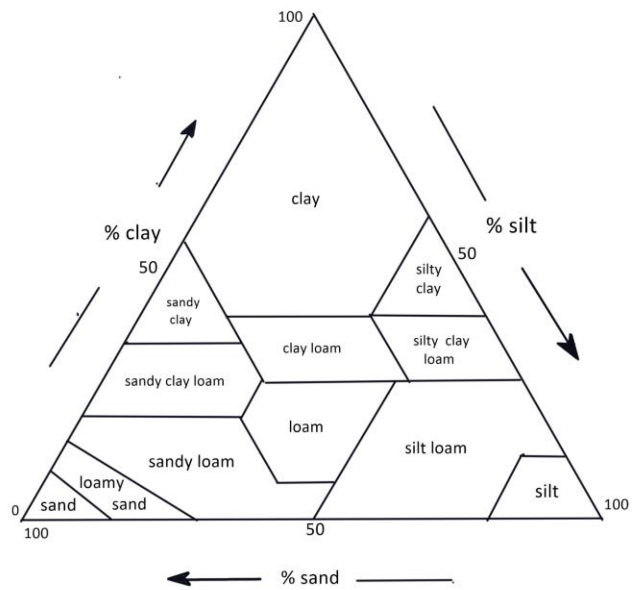
SOIL CHARACTERISTICS

All soils are a mixture of clay, silt and sand in various proportions, which is called loam. This diagram shows how the basic types of soil are made up. In reality, however, these constituents can be combined in an infinite number of ways so that each soil is unique to its locality.

Sand is easy to dig and work with, but will not hold water, or nutrients, well.

Silt is poor in nutrients, reasonably easy to work with, but holds water well.

Clay is difficult to work with and compacts easily, but holds water and nutrients well. Nutrients in this type of soil are not easily released to plants.



Once the chemical constituents of soil are in place plants can start to grow, and it is from this process that the biological components of the soil are built up. These consist of:

Dead forms of organic material – These are mostly dead plant parts, which make up about 85% of all organic matter in the soil. This is sometimes also known as humus, although there is some debate about how 'humus' should be defined. Sometimes it is defined as being all partly-decayed organic material, while others say it is only the dark brown/black material that is the fully decayed vegetable or animal matter. It is considered to be of great importance in soil as it provides nutrients for plants and increases the ability of the soil to retain water.

Living parts of plants – These are mostly roots which make up about 10% of organic matter.

Microbes and soil animals like earthworms – Although these make up only about 5% of the organic matter, they are crucial to two processes essential to plant life:

The first is the **process of decay** by which organic matter is turned into nutrients which can be absorbed by plants. The initial physical breakdown of organic material is carried out mainly by earthworms and larger soil-dwelling insects. Further breakdown of the organic matter is carried out by both bacteria and fungi.

The second is the process of **nutrient uptake** by which plants extract nutrients, especially nitrogen, from the air (known as nitrogen fixing) and nitrogen and phosphorus from the soil. This process is also facilitated by a variety of bacteria and fungi that work with plant roots by releasing the (organic) nutrients which the roots can then absorb. The precise ways in which these unseen organisms do this is narrated in the next section on microbes.

SOIL PROCESSES

Soil is not an inert substance. It plays a part in the long-term mineral cycles of the earth, with soil erosion being an important component of this process. Within the soil there are various biological processes which enable vegetation to grow, and ultimately nature as we know it to exist and be sustained.

SOIL EROSION

While soil is being created from the rock below the ground, at the same time it is being eroded from the top. It can start with heavy rain that loosens and carries soil towards fast flowing rivers. As these rivers eventually slow down, first the coarse material comprising cobbles, shingle and gravel settles down. Then sand, silt, and finally mud. In the flood plains of a river, silt and sand are deposited with some mud, creating some of the most fertile and workable soils of the world. In estuaries, under the influence of tides and waves, fine particles are washed out and sand flats are left behind. When the sea level drops, these become workable soils but remain poor in nutrients. Soil erosion also takes place with wind, especially in arid areas or where the soil has insufficient organic matter within it.

The problem is that at this point in the life of the earth soil is being lost much more quickly than it is produced, mainly because of human activity. Worldwide, agricultural soil is lost at a rate 10-40 times faster than its natural replacement. Globally, the loss of agricultural land is 0.5% of the total agricultural land available per year, and just over half (52%) of the world's soil is degraded. Every day we lose the equivalent of 30 football pitches of land to soil erosion and degradation. While this loss has increased in recent years, since the dawn of humanity the unsustainable use of land has been a factor in the rise and fall of many ancient and more modern civilisations.[1]

One of the worst experiences of soil erosion in recent years was during the 1930's 'dustbowl' events in the southern plains of the USA. The area was originally covered with grasses that held the fine soil in place, but was ploughed up by settlers to grow wheat crops that were in high demand during the first World War. This exhausted the topsoil, which was then overgrazed by cattle and sheep that stripped the soil of its cover. When a bad drought came, the uncovered soil turned to dust and much of it was blown away by the wind, affecting more than 100 million acres of land.

Modern industrial farming practices increase the possibilities for soil erosion. All too often soil has been seen as an inert substance to which other inert substances, in the form of fertilizers, are added according to the needs of the plants being grown. Soil is thus perceived as no more than a dry mix of chemicals, which can be 'improved' by adding yet more chemicals. The problem is that adding chemicals in this way

1. For a basic more detailed analysis of this, see 'Topsoil and Civilisation' by Tom Dale and Vernon Carter – published by the University of Ohio Press 1955

does not improve the texture of the soil, which can become very dusty and therefore more prone to erosion by wind and water.

NUTRIENT RECYCLING

In undisturbed soils humus builds up naturally through a process of decay. Living organisms are made up of thousands of different compounds, which after death decompose in the following stages:

The first stage of decay starts with the breakdown of compounds that are easy to decompose – like sugars, starches and proteins. Fungi and bacteria easily and quickly work on these substances, as these microscopic beings have the enzymes necessary to do this. Mites and small soil-dwelling animals, such as earthworms, help this stage by breaking up the organic matter into smaller pieces, exposing more of the material to colonisation by bacteria and fungi.

The second stage involves the microbes decomposing more complicated compounds such as cellulose (an insoluble carbohydrate found in plants) and lignins (a very complicated structure that is part of wood). Many, but not all, fungi and bacteria can decompose these compounds, as they are much larger and made up of more complicated molecules. Specific enzymes, not commonly produced by most micro-organisms, are required to break down these compounds.

The third stage, which can last from ten to thousands of years, comprises the decomposition of substances like waxes, phenols and other stable substances not easily accessible to soil organisms. It also includes humus-like substances. There are some human-made substances like plastic that will never decay, or will only do so at a rate that is much slower than the rate at which they are being made and discarded into the soil. It is only in the last few years we have started to recognise the negative effects of discarded plastic on all life on earth.

Decomposition takes place only if conditions are suitable both chemically and biologically. There must be some moisture available, soil temperatures must be suitable (usually between 10 and 35°C), and the soil must not be too acidic or alkaline. The exact types of organisms involved in breaking down the organic matter will depend on these conditions.

This cycle of decay is a very important one for the sustainable food-grower, as it is through this process that nutrients are both returned to the soil and made available to plants. For poor soils this is the main way of soil improvement and fertility preservation. Sustainable food-growers use this process when they make compost heaps that promote the process of decay of organic material into humus that plants can use as food. Since microbes are an essential part of this process, there is more information about this in the next section on microbes.

NITROGEN FIXING

This is carried out by a group of single-cell bacteria called Rhizobiaceae. The bacteria take nitrogen from the air (which plants cannot use) and convert it into a compound of nitrogen called ammonium nitrogen, which plants can use. The process is called nitrogen fixation, and these bacteria are often called "nitrogen fixers". To achieve this, the bacteria form a close association, called a symbiosis, with leguminous plants like beans, soya and clover. Nodules, white ball like structures, are formed on the plant roots in response to the presence of the bacteria, and it is within these nodules that the ammonium nitrogen is found. Most plants need very specific kinds of rhizobia to form nodules. For example, the rhizobia that form nodules on peas cannot form nodules on clover. Leaving these roots in the soil after the plant has died increases the nitrogen available for subsequent plants. I love to look at the roots of our bean plants to see these special nodules, which show that the bacteria in our soil have been at work.

MYCORRHIZAL ASSOCIATIONS

Mycorrhizal associations are symbiotic relationships between soil fungi and plants that enable plants to take up nutrients – in particular phosphorus, but also sometimes nitrogen, copper and zinc – from the soil. The name "mycorrhiza" means "fungus root", and this is derived from the close association of the fungi with plant roots – in fact, mycorrhizal fungi cannot complete their life cycles unless they are connected to plant roots.

There are four kinds of mycorrhizal fungi. Each of these four varieties are associated with different types of plants, although the most common fungi is the arbuscular fungi. They form an association with the plant roots with very thin, threadlike structures called hyphae that form networks between neighbouring soil particles, between roots and soil particles, between roots on the same plant, between roots of different plants (even different types of plants), and in the plant roots themselves. These networks enable the fungi to get their carbohydrate (energy) from the plant root they are living in/on, and they help the plants by transferring phosphorus from the soil into the root. Unlike nitrogen that moves with water, phosphorus has to be taken by the plant directly from the soil, and it is therefore necessary for roots to intercept the phosphorus in the soil before it can be taken up into the plant. What the fungi do is allow for a greater volume of soil to be explored by the plant for phosphorus. Thus, when phosphorus is scarce, plants that have developed mycorrhizas on their root systems can take up more phosphorus than plants with none or only small amounts of mycorrhizas.

Although some kinds of soil fungi can be associated with plant and animal disease, the arbuscular fungi can be very beneficial by decreasing the susceptibility of the plant to disease and drought. The mesh of hyphae over the surface of the roots can provide protection against pathogenic soil fungi, and also helps to hold and stabilize soil particles and therefore water. This enables the plant to access more water from the surrounding soil as well as creating a better soil texture. These effects on plant growth combine to make the associated plant more robust and increase its chances of survival.

SOIL FERTILITY

The vegetation a soil is able to support depends to some extent on climate, especially at the extremes of heat and wet. If evaporation exceeds rainfall, soils become arid resulting in deserts. If rainfall exceeds evaporation, soils become boggy. In both cases the soil's productivity is reduced considerably.

In tropical rainforests, rainfall exceeds potential evaporation by a factor of two, making the soil extremely vulnerable to erosion if the tropical rainforest cover is removed, as there is nothing to absorb the huge amounts of moisture. In deserts and dry soils, on the other hand, the reverse is the case, with evaporation exceeding rainfall by a factor of two. In both cases these soils should either be left alone, never to be exploited by modern farming, or be farmed with the utmost care.

Soil fertility is the combined effects of three major interacting components that are:

Physical

Chemical

Biological.

The physical aspects of soil, especially its texture and structure, have a profound effect on the growth of plants. Water movement through the soil is determined by texture and structure, as is the ability of the plants to obtain oxygen through their roots. A finely textured soil will hold too much moisture, and will not allow the roots to breathe properly. A coarse soil will allow the water to go through much too quickly, and the plants will be unable to obtain the necessary nutrients from the soil.

Of great importance is the top layer of the soil, especially in tropical climates, where most of the bacterial activity takes place. It should not get compacted, and this is particularly important for clay soils, for otherwise a hard crust is formed that does not allow the necessary free passage of water and air. From a practical point of view, people should try not to walk on the soil where plants are to be grown.

It is important to know what the main constituents are in the soil that one is dealing with, so that appropriate action can be taken to create a soil that promotes maximum plant growth.

Soils that have a large proportion of clay in them have the most nutrients, but these are not necessarily available to the plants. This soil absorbs excess water, which can starve the plant roots of oxygen as well as making it very heavy to work. Much of the soil in Buddha Garden is like this.

Soils with a large amount of silt in them have good water retention abilities, but have less nutrients in them than clay soils.

Soils containing a large amount of sand are very easy to work, but have few nutrients and there is little water retention.

Whatever the soil type, all benefit from the application of more organic matter, and for sustainable farmers this is the main way of improving and maintaining soil fertility. Organic matter improves the texture of clay soils, making them less likely to waterlog, as well as providing more soil-dwelling creatures (earthworms, bacteria and fungi) that allow plants to access soil nutrients. The same is true for silty soils that need the extra nutrients. In sandy soils, organic matter provides both nutrients and improves the water retention properties of the soil. The nutrients available to plants and the soil-dwelling creatures that can help the plants absorb them can also be enhanced by the use of 'green manures,' which are plants that when grown bring nutrients (mainly nitrogen), bacteria and fungi to the soil.

It must be remembered, however, that soil characteristics can vary considerably from place to place. Soil types can differ widely because of local conditions, such as elevation above sea level, the level of the ground water, and the slope of the land. This means that on earth there is an almost infinite number of different soils, each having its own needs, so that careful observation and application is required to enable the best way of using them. This can be seen in even a small place like Buddha Garden where the soil from different parts of the farm is very different.

Soil temperature is important for both germination of seeds and growth of seedlings and larger plants. In soil that is too hot, the micro-bacteriological activity will be reduced, making it difficult for the plant to absorb the necessary nutrients. Similarly, for soil that is too cold. In both cases the soil needs to be protected by mulch, which is a layer of organic material that protects the soil from extremes of either heat or cold, thus maximizing bacteriological activity. Mulch also protects it from the effects of heavy rain and strong wind, thus preventing erosion.

Whether the soil is acidic or alkaline has relevance for the sort of plants that can be grown there. Acidity is measured by the 'pH value'. A totally neutral soil (one that is neither acidic or alkaline) has a pH value of 6. The best soils are slightly acidic, with a pH value of 6.2–6.5. The pH value of soil can be changed by adding naturally-formed chemicals. A soil that is too acidic can be improved by the addition of lime or gypsum; a soil that is too alkaline can be improved by the addition of sodium bicarbonate.

SOIL IMPROVEMENT AND MAINTENANCE

To improve soil in a sustainable way it is necessary to copy techniques that are found in nature. Sometimes it may be necessary to intensify a natural process, such as in the making of compost (which intensifies the process of decay) or in the use of green manures (which fixes nitrogen from the air to the soil). Best results are obtained from using a range of techniques according to the needs of the soil and the kind of crops being grown. Once you start working with soil it will respond, and this in turn will provide you with pointers as to what you should do next.

Different methods that can be considered are as follows.

IN SITU MANURING

In this method the manure is provided by animals or plants at the site where it is needed. The two main methods are as follows:

Animal manuring is carried out by allowing animals such as cows, goats and chickens free movement on the land just after the crop has been harvested. The animals can feed on remaining crop residues, and at the same time clear the land and help to break up the soil. The manure these animals drop helps to improve the soil's texture and nutrient value before the next sowing season. Farmers can offer their already-harvested plots for grazing to animal owners if they do not have animals on their own farm. This facility is very useful for farmers who have small plots of land, for it enables them to save on transport and labour charges of bringing lorry loads of animal manure into the farm. We used to use this method with our chickens in Buddha Garden, where we had a series of yards where the chickens would be let into after each crop. When we decided to have fewer chickens this method did not work, as there were too few chickens to provide the manure that we needed. We therefore discontinued doing it and put all the chickens into a pen, which had the advantage of a roof which kept out animals that preyed on them.

'Green manuring' involves growing a quick-growing crop of leafy plants that is incorporated in the soil at an early part of their life-cycle before flowering. This provides nutrients to the soil and improves its texture. Often the growing plants also protect the soil against erosion and the leaching of minerals from the soil by water and wind. It is an inexpensive way of improving yields, and is very important on farms that do not have access to animals. An important part of weed control, green manures cover the soil very thoroughly and can be grown with crops if sufficient care is taken. Some green manures can also be grown and harvested specifically with the purpose of providing mulch to cover the ground in which the crop is to be planted. This results in preventing weed growth, protecting the soil from erosion, and keeping the soil moist for optimum bacterial activity. Some green manures used in India include:

Sesbania aculeate (dhaincha) suitable for loam and clay soils and insensitive to drought and stagnation of water, with good yields.

Sesbania speiciosa is a good green manure for those growing rice and can be grown on a wide range of soils and on bunds.

Sesbania sostrata copes well with flooding by producing root nodules. It can be raised as seedlings and planted in rice fields on the bunds.

Sun hemp is a quick growing crop ready for incorporating in the soil at around 90 days after sowing. It can also be grown to maturity and cut to make good mulch.

is a good dual-purpose green manure that improves the soil while also producing cattle fodder.

Velvet bean is an excellent leguminous plant that grows quickly and strongly while bringing large amounts of nitrogen to the soil. When cut after the plants have matured it makes a very good mulch. In the beginning we used this in Buddha Garden with much success. Velvet beans need to grow for quite a long time (at least three months; and six months is better) and cannot be grown with food plants as it is far too aggressive. An Auroville farmer who planted it around her cashew trees found that it grew all over the trees. It is an excellent way to start improving soil fertility.

Crop rotation means that the same crop is never grown in the same place twice. Crop rotation can be planned on different time scales – over several months within a season or over several years depending on the climate and the crops. The aim of the rotation should be to grow crops in a sequence that balances soil nutrient demands, limits soil and insect attacks, and deters weeds. To balance nutrient demands, crops can be divided into four categories as follows:

Leafy plants, such as lettuce, salad greens, spinach and broccoli that require a lot of nitrogen.

Fruits that need phosphorus, such as squashes, cucumbers, melons, pumpkins, tomatoes, peppers and eggplants.

Roots that love potassium, such as onions, shallots, garlic, scallions, leeks, carrots, beets, turnips and radishes.

Soil builders and cleaners: Legumes, such as beans and peas, are excellent soil builders because they store nitrogen from the air in their roots and release it into the soil. Examples of soil cleaners are corn and potatoes.

Crops from each category are grown in rotation, balancing deep and shallow rooting plants as each takes nutrients from different parts of the soil bed. Crop rotation can also break the cycles of pest and disease problems that build up in soils when the same crop is planted repeatedly. The rotation is planned so that no two crops subject to similar diseases follow one another within the disease's incubation period. The same principle holds for insect pests: if crops are rotated it makes it harder for emerging insects to find their preferred food.

EX SITU MANURING

In this method, organic material is brought to the land and incorporated into the soil. Some farmers feel that it is best if such material comes from the farm itself, but if the soil is very poor external inputs will be needed, which may not be too expensive if they are the waste products of another process. Materials that can be used include:

the dung and urine of animals

the by-products of the slaughterhouse, especially blood and bone

crop residues from cereals, pulses, oilseed and vegetables

leaves and forest waste, including wood

- rural and urban solid waste
- agro-industrial products such as oil cakes, paddy husk and bran, fruit and vegetable waste, teas and tobacco waste.

If an organic farmer is to use this waste, however, it is important to find out whether these residues contain any polluting substances. Generally, before such waste is incorporated into the soil, it must be composted. As Buddha Garden has developed we have tried to rely less and less on such external inputs, as it had become more and more difficult to obtain materials that are not contaminated with chemicals and other pollutants. When Buddha Garden first started, we used to use rice straw as a mulch and for compost. But this was difficult to find, hardly ever organic, and very expensive because for local farmers it is an important part of cow food.

COMPOST

A compost heap is simply an environment that speeds up the natural process of decay. To encourage a strong population of micro-organisms favourable conditions, namely food, warmth, moisture and air, must be provided for their growth. Therefore the compost heap must be constructed in a way that allows for these needs. A compost heap requires:

- **A proper ratio of carbon-rich materials, or "browns", and nitrogen-rich materials, or "greens"**: The carbon material provides energy for the microbes, and the nitrogen provides them with protein. The carbon/nitrogen balance of the heap needs to be correct, as with too much carbon the pile breaks down too slowly and with too much nitrogen material there will be a bad smell. Carbon (brown) materials comprise dry organic matter such as dry leaves, straw and wood chips. Nitrogen rich (greens) are fresh or green, such as grass clippings and kitchen waste. Manure from any animals except carnivores (as it can contain dangerous pathogens) contains both large amounts of nitrogen as well as many beneficial microbes. Ash (from wood or paper, but not coal) can also be used in small quantities to provide potassium without making the pile alkaline. Achieving the best mix of materials is more often an art gained through experience than an exact science. Substances that should not find their way into the compost heap include plastic (even the biodegradable kind leaves a poisonous chemical residue) as well as certain organic materials like eucalyptus leaves, as it will make the soil acidic in tropical climates (in different climates there will be different sorts of leaves that are not appropriate). Paper products can be composted provided the proportion is not too great and they are not contaminated with chemicals, like the lead in some printing inks, or is lined with a layer of aluminium foil or plastic. For this reason we never put paper in our compost heap. Tough material like sticks and some tough leaves are better cut into small pieces or ground up before being put on the heap, so that they compost more easily. A little soil in the heap (perhaps from the roots of weeds) provides some of the soil bacteria, which will multiply and aid the decay process.
- **A high-enough temperature**: The temperature of the managed pile is important. If it is hot this indicates that the decomposition process is taking place. It should be high enough to kill off seeds and pests. A temperature between 40 and 60 degrees celsius is considered optimum. The easiest way to track the temperature inside the pile is by feeling it. If it is warm or hot, everything is fine. If it is the same temperature as the outside air, the microbial activity has slowed down and more

nitrogen (green) materials, such as grass clippings, kitchen waste, or manure, need to be added to speed up the process.

A correct amount of moisture: This is essential to microbial activity and to the biochemical process of decay. If the pile becomes too dry, which can happen rather easily in the Auroville hot season, the decay process will slow down. The pile should feel as moist as a wrung-out sponge. If very wet materials are being used, however, they need to be mixed with dry materials such as leaves, as the compost heap is built. If all the material is very dry, then the pile needs to be soaked with a hose as it is being created. Too much water is just as detrimental as lack of water. In an overly wet pile, water replaces the air, creating an anaerobic environment, which slows decomposition and releases a bad smell.

Air circulation: This is an important element in a compost pile. Most of the organisms that decompose organic matter are aerobic – they need air to survive. There are several ways to ensure that this happens. Firstly, if materials that are easily compacted, such as ashes or sawdust, are used they should be mixed with coarser material, such as leaves and straw. The heap can also be built on a platform of branches or have ventilation tubes in it to maximize air circulation. Another way to ensure there is sufficient air is to turn the pile over from time-to-time, although this is very labour intensive. Doing so has the advantage of making sure that the contents of the pile are evenly distributed between the centre and outside, so that a more even decomposition of the material takes place.

The placing of the compost heap: In hot climates the compost heap is best placed in the shade (or covered) and close to a source of water so that it can be watered regularly. In cool climates it is best put in a sunny place so that the temperature is maintained as high as possible. The heap should be placed on soil rather than cement or asphalt to take advantage of the soil bacteria and earthworms. Making compost on a bed that will be used for planting after the compost has been utilized is a very energy efficient way of improving the soil.

The importance of compost to organic farmers cannot be overstated as it:

functions as a strong conditional agent for the soil by helping to break up clay soils and binding together sandy soils;

holds up to six times its own weight in water, thus improving the water retention capacity of the soil and creating a barrier to flooding and erosion;

improves the health of soil organisms by nurturing earthworms and beneficial fungi that fight nematodes and other soil pests;

helps to balance the acid/alkaline level in the soil;

contains micro-nutrients, such as nitrogen, phosphorus, potassium, magnesium and sulphur, which are essential to plant growth. It has also been proved that plants grown in a well-composted soil are less likely to take up heavy metals and other urban pollutants;

helps recycle all the organic waste on a farm – the farmer returns to the soil all that has been taken out in the process of growing crops, thus making the farm more sustainable.

HOW WE MAKE COMPOST IN BUDDHA GARDEN

We have developed what may seem to others a somewhat rough and ready way of making compost. Yet it works for us and is suitable in our climate. It uses the readily available materials we have from within the garden, and we have set up an infrastructure that makes it easy for the people who come to help us. Interestingly, we have had to modify the compost-making process for other student gardens in Auroville because they were producing much less suitable organic material.

To make a compost heap we do the following:

We start by creating a layer of sticks and other hard material at the bottom of the heap. This helps air to penetrate the heap and circulate.

On top of this we spread layers of brown (dead) organic matter followed by green (fresh) organic matter. The layers of brown material are twice as thick as the layers of green material. We have found this ratio of brown and green material balances the bacteria in the heap so that it does not smell. If it does start to smell, we just add some more brown material.

As we build up the layers we water the heap, and sometimes we add chicken dung or EM (Effective Micro-organisms).

We have built four compost bins, which are made of brick to be the right size and shape (a cube) for the compost we need. They are built under a tree so that the compost does not get too hot, and there is a tap nearby in case we need to water the heaps.

During the first month, we water the heap at least twice a week to keep it damp. For the next four weeks we water according to the weather and season (compost made in the hot season will need extra water during this time) and then we leave it until it is ready to use. The compost is usually ready to use after 3–4 months. Anything not broken down is put into the next heap.

It is only possible to make compost in this way, with layers, if you have sufficient brown and green material. Since we get our brown material by the tractor load from other Auroville communities, and produce a lot of weeds and grow glyricidea as a green crop, we have never had a problem with that. Trying to make compost with our school groups was trickier. It was sometimes difficult to find enough leaves, and the weeds generated were often insufficient to create a layer for even a very small compost heap. What used to happen was that untidy piles of leaves and weeds would build up in different parts of the garden. Very often they would start to compost on their own, and it would be difficult to pull them apart and make a proper compost heap.

Now what happens is that at the end of every work lesson we get together all the leaves and green material that we have managed to collect. We make sure that there is about two-thirds brown and one-third green and then mix it up together. We then spread a layer of this mixed material on top of the heap that we water. We have found that doing this at the end of every class not only tidies everything up, but also demonstrates in a meaningful way to the students that in nature there is no waste – weeds and leaves that we sweep up are a precious resource for creating/sustaining the fertility of our soil.

VERMI COMPOSTING: This is a method of composting that uses red earthworms, also commonly called red worms, to consume organic waste, producing castings (an odour-free compost product for use as mulch), soil conditioner, and topsoil additive. Naturally-occurring organisms, such as bacteria and millipedes, also assist in the aerobic degradation of the organic material. This greatly decreases the time needed for composting to take place and produces a very high quality and potent humus.

COMPOST TEA: This can be made in a variety of ways. One method is to take solid compost, soak it in water, and let the mixture sit around for a few days. Then the liquid can be strained to take out the solid material. This liquid or compost tea can then be poured onto the plants. Another form of compost tea is cow urine that has been diluted with water. This provides plants with a lot of nitrogen. Both forms are mild enough to put on plants as they grow.

EM: The concept of effective micro-organisms (EM) was developed by Professor Teruo Higa, University of the Ryukyus, Okinawa, Japan (Higa, 1991; Higa and Wididana, 1991). EM consists of mixed cultures of beneficial and naturally occurring micro-organisms that can be applied as inoculants to increase the microbial diversity of soils and plant. This improves soil quality, soil health, and the growth, yield, and quality of crops. EM contains selected species of micro-organisms, including predominant populations of lactic acid bacteria and yeasts and smaller numbers of photosynthetic bacteria, actinomycetes, and other types of organism. All of these are mutually compatible with one another and can co-exist in liquid culture. EM is not a substitute for other organic farm practices, such as crop rotations, use of compost, conservation tillage, crop residue recycling, and bio-control of pests, but optimises them all.

As mentioned before, making compost is an art. Part of that art is finding a way of making compost that uses material that is available and is integrated with your other food growing activities. The method also of course has to be suited to the climate. The best way to find out what method best suits you is by trial and error.

BASIC PRINCIPLES FOR LOOKING AFTER YOUR SOIL

Focus on soil quality: The quality of what you grow depends on the quality of your soil. Time spent improving and maintaining soil fertility is never wasted. It is the bedrock of all successful sustainable food growing.

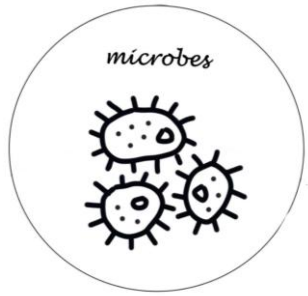
Know your soil: You don't necessarily need to do a soil test (although this can be helpful), but you do need to know your basic soil qualities in all parts of the area that you have under cultivation. However poor the soil it is always possible to build it up to a degree that it will be suitable for food growing. If necessary start with a (very) small area, and improve that as it has been shown that quite large amounts of food can be grown on a small piece of really fertile soil if it is properly managed. It is better to make a small piece of land really fertile rather than spread your efforts over a larger piece of land that ends up being less fertile. Be sensitive to how the soil responds to your work with it. Allow the soil to show you what it needs.

Preserve the soil's fertility by:

Adding organic matter in the form of compost or decaying material and mixing it with soil after every harvest. By a process of trial and error you will find out the best way of making compost in your place and climate.

Following a good crop-rotation process to help keep the soil in good condition as it stops the build-up of pests. It should include nitrogen-fixing plants as these put nutrients back into the soil. Create as much diversity as you can in terms of what you grow. This in turn will create a diversity of soil creatures and micro-organisms similar to those found in nature. This is the best way of helping to keep soil pests under control.

Mulching to keep the soil at an optimum temperature and help protect the bacterial action in the soil – especially in tropical areas. It also prevents erosion from wind and heavy rain.



As I was writing this section of the book I had to remind myself on several occasions that until the year 1676 any kind of microbe had never been seen or identified. It was only towards the end of the nineteenth century that more was discovered about these organisms, which eventually led to the medical breakthroughs of the twentieth and twenty first century, especially in treating infectious diseases. It is only in the last fifty years that the characteristics and complex organizations of these many different sorts of organisms have become apparent. With this has come a different understanding of how these organisms work within the human body, which has opened up new avenues for exploring how they can be used to promote health and heal disease. Very recently, new discoveries about how microbes are essential to various environmental processes has given us a different understanding about many aspects of food growing.

What follows is a basic description of the microbes relevant to food growing. Be aware that this is a rapidly-changing area of knowledge. This means that it is quite likely that new discoveries will lead to new ways of working with microbes, which could have very beneficial effects for food growers.

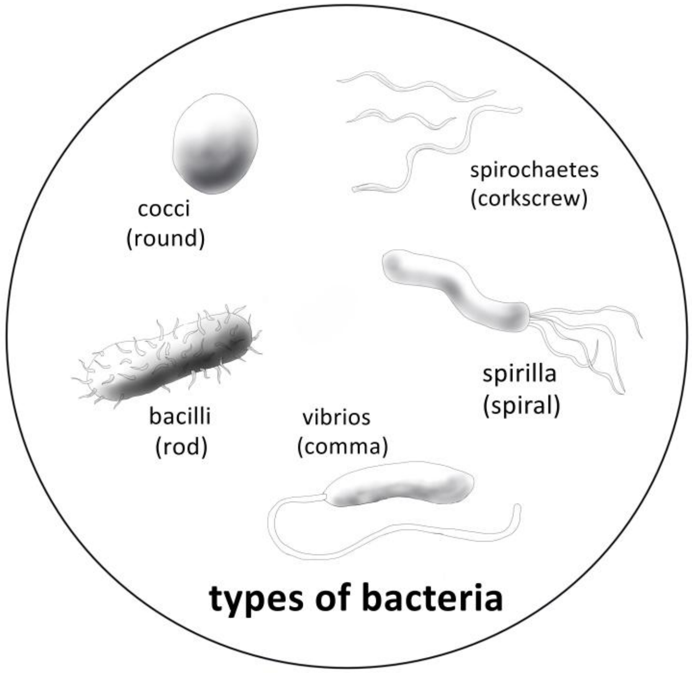
WHAT IS A MICROBE?

Sometimes referred to as micro-organisms, microbes are tiny living organisms. Most of them are invisible to the naked eye and can only be seen with a microscope. Microbes can be multi-cellular or single-celled organisms, and include bacteria, protozoa, and some fungi and algae. Micro-organisms occur in an amazing variety of shapes and sizes, and are divided into six groups.

1.1 BACTERIA

Bacteria are single-celled microbes with a cell structure which is simpler than that of other organisms. They have no nucleus, and their control centre containing the genetic information is just a single loop of DNA. Some bacteria have an extra circle of genetic material called a plasmid that often contains genes, which give the bacterium some advantage over other bacteria. For example, it may contain a gene that makes the bacterium resistant to a certain antibiotic.

Bacteria are classified into 5 groups according to their basic shapes: spherical (cocci), rod (bacilli), spiral (spirilla), comma (vibrios) or corkscrew (spirochaetes).



They can exist as single cells, in pairs, chains or clusters.

Bacteria are found in every habitat on Earth: soil, rock, oceans and even arctic snow. Some live in or on other organisms including plants, animals and humans. Some bacteria live in the soil or on dead plant matter, where they play an important role in the decaying process and the recycling of nutrients. Some types cause food spoilage and crop damage, but others are incredibly useful in the production of fermented foods, such as yoghurt and soy sauce. Relatively few bacteria are parasites or pathogens that cause disease in animals and plants.

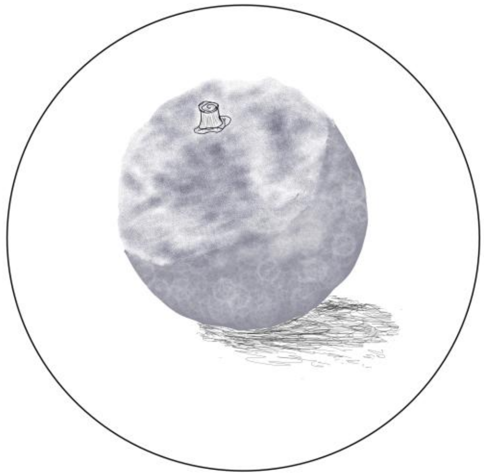
1.2 FUNGI

Fungi covers a wide range of organisms that range from single-celled organisms invisible to the naked eye to very complex multi-cellular organisms, like mushrooms. They are found in just about any habitat, but most live on the land, mainly in soil or on plant material, rather than in sea or fresh water. A group of fungi called the decomposers grow in the soil or on dead plant matter, where they play an important role in the breaking down and recycling of carbon and other elements. Some are parasites of plants causing diseases, such as mildews, rusts, scabs or canker. A very small number of fungi cause diseases in animals and humans. These include skin diseases, such as athletes' foot, ringworm and thrush.

There are three major groups of fungi; molds, mushrooms (multicellular filamentous molds), and yeasts.

MOLDS

We can see and sometimes smell molds depending on their type and where they are. They look like black or other coloured patches on plants, the soil, and sometimes on surfaces within a house.



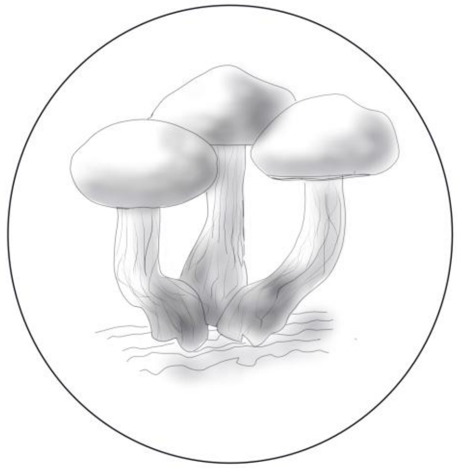
Molds are made up of very thin threads (called hyphae), which as they grow and intertwine form a network of threads called a mycelium. They do this on different sorts of organic matter, which they use for food. As the hyphae grow they excrete digestive enzymes or juices that break down the organic matter on which the mold has settled for its nutrient needs. Hyphae act as roots, anchoring mold to its substrate and absorbing nutrients just as roots do for plants.

Eventually some of the hyphal branches grow into the air where spores form. These clusters of hyphae are the coloured patches that we see. Spores are specialized structures and similar to seeds. They have a protective coat that protects them from high temperatures and drying out. These microscopic spores are eventually released into the air, where they either drift with wind or rain or are carried by insects to a new area with the requisite water and nutrients to fuel reproduction.

Despite their size and seemingly delicate nature, spores are hardy organisms. In many cases they can remain dormant for years, even under inhospitable hot and dry conditions. As fungi cannot move, they use spores to find a new environment where there are fewer organisms to compete with for their food.

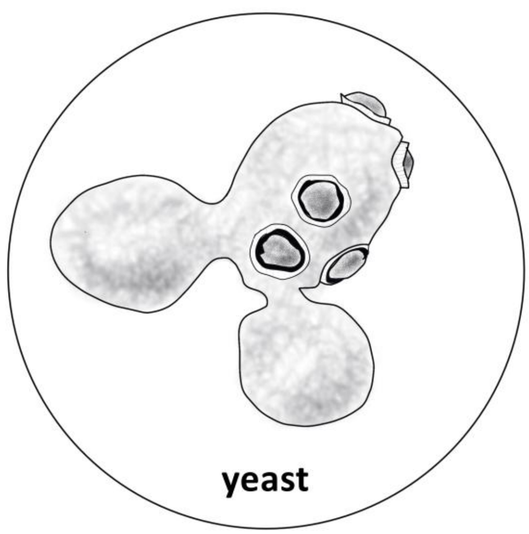
In Buddha Garden we are happy to see a lot of different molds in our compost heaps, as along with various other microbes they are helping to break down all the organic matter into plant food. Not welcome at all are the molds that we sometimes see on plants, particularly during the monsoon when it is very wet and humid. Our response to any such infestations is to remove the parts of the damaged plants or sometimes even the plants themselves. The best defense against mold on plants is sun, which is why during the wet times of the year we have to make sure that plants susceptible to mold are not planted too close together, and are planted on beds that get as much sun as possible. Then whatever sun we have during this time can penetrate the plant and help to keep the level of mold down.

MUSHROOMS OR MACROSCOPIC FILAMENTOUS FUNGI



Like molds, macroscopic filamentous fungi also grow by producing a mycelium below ground. They differ from moulds because they produce visible fruiting bodies (commonly known as mushrooms or toadstools) that hold the spores. Sometimes the group of fungi is referred to as 'mushrooms', but the mushroom is just the part of the fungus we see above ground. The scientific name for this is the fruiting body. The fruiting body is made up of tightly packed hyphae which divide to produce the different parts of the fungal structure. Gills underneath the cap are covered with spores, and a 10 cm diameter cap can produce up to 100 million spores per hour.

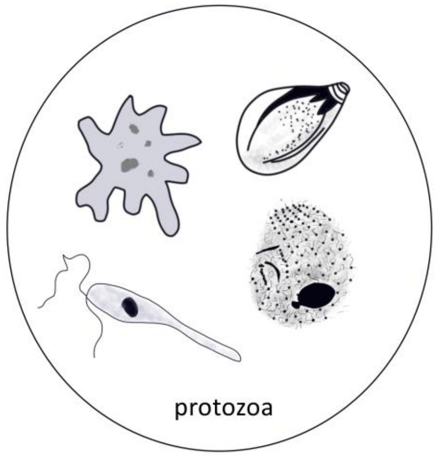
YEASTS



Yeasts are small, lemon-shaped, single cells that are about the same size as red blood cells. They multiply by budding a daughter cell off from the original parent cell. Scars can be seen on the surface of the yeast cell where buds have broken off. Yeasts, such as Saccharomyces, play an important role in the production of bread and in brewing. Other species of yeast, such as Candida (also known as thrush), are opportunistic pathogens and can cause infections in individuals who do not have a healthy immune system.

PROTOZOA

Protozoa are single celled organisms. They come in many different shapes and sizes ranging from an Amoeba that can change its shape to Paramecium with a fixed shape and complex structure. Some of them have hairs called cilia or long thread like structures called flagella that help them move.

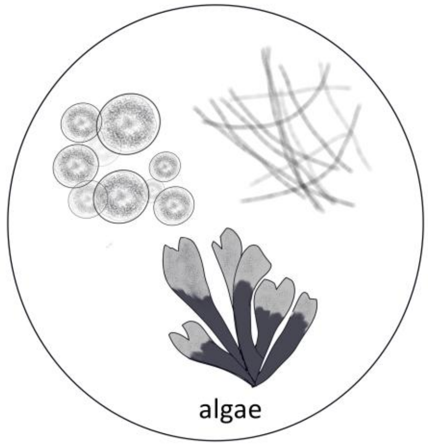


They live in a wide variety of moist habitats including fresh water, marine environments and the soil. Some are parasitic, which means that they live on other plants and animals including humans, and can cause disease. A certain kind of amoeba that we have in local water causes diarrhoea and a protozoa called plasmodium causes a nasty form of malaria.

Protozoa are extremely abundant, and well distributed in the entire thickness of the first few centimetres of soil everywhere. Their geographical distribution covers climates that extend from the warm and dry areas typical of deserts to cold and damp ones typical of the tundra. These organisms play very important roles in the soil. Some of them make a close relationship with plant roots and help them absorb nutrients from the soil. Others are part of the nitrogen-fixing cycle, and some are part of the decomposition cycle. These organisms help keep a check on the bacterial population in the soil, thus keeping bacterial pests in check.

ALGAE

These can exist as single cells, or joined together in chains or they can be made up of many cells like various sorts of seaweed. Most algae live in fresh or sea water where they can either be free-floating (like plankton) or attached to the bottom on rocks, soil or vegetation. It is important for these organisms to have enough moisture. A few algae form very close partnerships with fungi to form lichens.

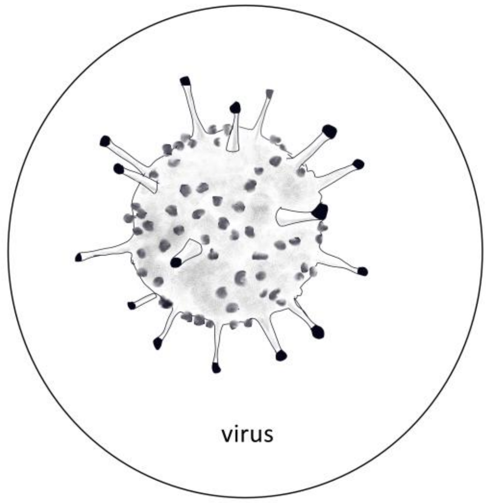


All algae contain a pigment called chlorophyll, and like plants they make their own food by photosynthesis. The chlorophyll gives many algae their green appearance. However, some algae appear brown, yellow or red because in addition to chlorophyll they have other accessory pigments that camouflage the green colour.

Interesting types of algae are diatoms and archaea. Diatoms float in the sea and their cell walls contain a hard substance called silica. When diatoms die they sink to the floor and their soft parts decay and the silica cell wall remains. Over time the pressure of the seawater pushes the silica together to form one large layer. This silica is then mined from the seabed, crushed, and used in abrasives and polishes such as toothpaste. Archaea can have many different shapes, and many are found living in extreme environments that are very hot, very cold, or in water which has a high salt concentration. Their cell wall differs in structure from that of bacteria and is thought to be more stable in extreme conditions, which helps to explain why some archaea live in many of the most hostile environments on Earth.

VIRUSES

Viruses are the smallest of all the microbes. They are said to be so small that 500 million rhinoviruses (which cause the common cold) could fit on to the head of a pin. They are unique, because they can only live and multiply inside the cells of other living things. They cannot exist on their own, as they are not cells and cannot replicate themselves. They have to rely on host cells for the production of energy, reproduction, and for their survival. For this reason, their status as a living organism has been called into question. Bacteriophages account for the majority of the viruses present on Earth.



Some of the viruses infecting humans are capable of causing severe and often lethal diseases such as covid-19 and ebolla, but other viruses can be manipulated to be beneficial to human health. Viruses are being medically used as carriers that take material for treatment of a disease to various target cells. They have been studied extensively in management of inherited diseases and genetic engineering as well as cancers. These are highly specific viruses that can target, infect, and (if correctly selected) destroy pathogenic bacteria. Viruses offer the potential to cure cancer, correct genetic disorders, or fight pathogenic viral infections.

MICROBES AND LIFE

The importance of this unseen world of microbes to life on earth and to human health is gradually being discovered. It has been found that the human body has many different sorts of micro-organisms within it, most of which are essential to our bodily functions. The traditional estimate was that humans live with ten times more non-human (i.e. microbes) than human cells, although more recent estimates have lowered this ratio to 3:1 non-human to human cells. We are born with no bacteria in or around us, but within seconds of our birth we have been colonized with bacteria. They live in our mouths, around our eyes, in our digestive systems, under our arms, and in the shoots of our hair. Most are helpful or at least harmless.

The aggregate of all these micro-organisms is known as the "human microbiome", and it performs tasks that are known to be vital to the human body. For example, our digestive system is home to up to two kilos of a whole host of different microbes that are essential for digesting our food. Other microbes help to build up our immune system, thus protecting us from disease, while still others help to detoxify our bodies from various poisons. The surfaces of the human body inside and out, for example the skin, mouth and the intestines, are covered in millions of individual micro-organisms that do not do us any harm. Known as the normal "body flora", they can help to protect us from becoming infected with harmful microbes.

Scientists know the bacteria inside our gut can influence our maturation, immune system development, metabolism, and production of essential bio-compounds. Previous research shows that a number of diseases – including cardiovascular disease, diabetes and inflammatory bowel disease – are associated with changes in our gut bacteria or microbiota. Some have been linked to obesity. So far, the practical application of this sort of knowledge is limited. This is mainly because we know relatively little about the hundreds of species of bacteria living in and on our bodies, or how they interact both with each other and their human host. Considerable research is needed to determine firstly the precise ways in which the human microbiome affects human health, and secondly how the human microbiome can best be targeted to restore health.

MICROBES AND THE SOIL

Soil microbiology is the scientific discipline concerned with the study of all biological aspects of the micro-organisms (bacteria, archaea, viruses, fungi, parasites and protozoa) that exist in the soil environment. Soil can be seen as a living system consisting of a diverse group of micro-organisms. The so-called soil ecosystem is similar to the human microbiome. Like the human microbiome, research on the soil ecosystem has only just begun, but already has much to teach us.

HOW MICROBES HELP PLANT GROWTH

Microbes play an important role in the health and vitality of plants. Microbes break down large pieces of organic matter and turn them into much more simple chemical components. These are the decomposers that deal with dead plant and animal matter. If these recyclers did not do their job, the world would be a heap of unusable rubbish. Instead, recyclers use the organic matter to release the fundamental components that are used as food by plants. The microbes that work in this recycling role use the organic carbon in the organic matter as an energy source (food). Recycling frees up nutrients like nitrogen, potassium and phosphorus that are important to plant health. The importance of these recycling microbes cannot be overstated – they turn the world's refuse into the building blocks of life. The maintenance of plant-life and, therefore, life on earth would be nearly impossible without them.

Some soil micro-organisms work on nearby rocks and minerals and create a kind of "bacterial goo" – scientifically called an "exudate". This has a special pH and other key characteristics, specially formulated to bind and extract nutrients like phosphorus, calcium and potassium. All of these minerals are needed for healthy plants and good crop yields. A specific group of these micro-organisms already described are the mycorrhizal fungi, which form a special symbiotic relationship with plant roots.

In a similar pattern some plants conspicuously modify their soil environment by exuding large amounts of carbon from their roots. Known as rhizospheres, this area becomes a biological hotspot in the soil. Adding carbon to the soil surrounding the roots leads to a huge increase in the number of micro-organisms living within and outside the roots. These root exudates are composed of a complex mixture of low-molecular weight compounds, such as amino acids, organic acids, sugars and phenolics. Root mucilage, a carbon-rich gel layer surrounding the root tip, also provides a similar complex mixture of chemicals. It is this which attracts rhizobia bacteria responsible for taking the nitrogen from the air and processing it into a form usable by the plant. Owing to this special symbiotic relationship, legumes make good cover-crops when the soil is not being used for growing crops.

Nitrogen is an essential nutrient for plant growth and development, but is unavailable to plants in its most widespread form as atmospheric nitrogen. In modern agriculture much of this required nitrogen is provided to cropping systems in the form of industrially-produced nitrogen fertilizers. As well as being expensive, use of these fertilizers has led to ecological problems worldwide. This biological nitrogen fixation, on the other hand, offers a natural means of providing nitrogen for plants. It also means that the farmer is not required to spend as much time, money and energy in applying nitrogen fertilizers.

VIRUSES

There has been little research on plant viruses, except for those that are a problem to plants. Yet research has shown that they could well have positive effects. In the geothermal areas of Yellowstone National Park, where the soil temperatures are very high, so-called panic grass grew in soil temperatures of 115°F. The researchers found that a fungus growing on panic grass enabled the plants to thrive in these temperatures. They also found that when there was a certain virus on the fungus the plants grew even better.

EFFECTIVE MICRO-ORGANISMS (EM)

Increasingly, research is demonstrating the sometimes very complex relationships between plants and microbes. What is less easy to demonstrate is how to manipulate these relationships in a way that will be beneficial for farmers. Farmers have long been using animal manures and composts, which have natural populations of a huge diversity of micro-organisms. Many of these exert beneficial effects when introduced to the soil, but are soon overtaken and sometimes suppressed by the existing micro-organisms of the soil ecosystem. Building on their increasing knowledge of the bacteria involved and their relationship with each other, the soil and the plants, micro-biologists have developed what are called Effective Micro-organisms, also known as EM. This consists of billions of beneficial micro-organisms that have been isolated and grown into a solution that can be added to the soil. They consist mainly of photosynthesizing bacteria, lactic acid bacteria, yeasts, actinomycetes and fermenting fungi.

It was thought that the main advantage the effective micro-organisms had over the natural organisms was that in the EM the beneficial micro-organisms were in much greater numbers and optimally balanced than in the natural situation. It was therefore assumed they would persist in the soil environment for a longer time, enough to bring about beneficial effects such as improved plant growth and suppression of soil diseases.

Research on the original EM (developed by Dr Teruo Higa in Japan) showed that effects on the soil were inconsistent, and that what positive changes there were could not necessarily be ascribed to the micro-organisms. A three-year study in Zurich found that the positive benefits from Bokashi (a form of EM made with rice husk) could be attributed to the carrier (the rice husk) rather than the micro-organisms. Yet a twenty-year study in China showed that over the long term the application of EM in combination with compost significantly increased wheat straw biomass, grain yield, straw and grain nutrition compared to traditional compost and control treatment.

It seems there is no silver bullet when it comes to showing how soil ecology can be improved in a way that will also improve plant growth and production. The last fifty years of research on this subject has thrown up some tantalizing possibilities of how this might be done, although the scientific evidence for its efficacy is inconsistent. It may be that the soil ecology of individual soils needs to be known, and that such soil will need unique solutions based on that individual ecology to produce consistent improvements. Soils differ, and it is possible that improving the ecology of a particular soil will be as individual as improving the bacteria of a human microbiome. In the meantime, perhaps the best we can do is to preserve the diversity of the soil's microbiome by being aware of its importance and taking the necessary steps to do this. One of the most important ways is to make compost, which brings together a wide range of insects and micro-organisms to break down waste material into plant food.

COMPOSTING AND MICROBES

Farmers have always known that compost was helpful for growing plants and improving soil health. What they did not know was how or why it worked. Over the last one hundred and fifty years this has – and continues to – become gradually clear. Composting is a way of speeding up the natural process of decomposition by providing optimum conditions so that organic matter can break down more quickly. This process of decomposition depends mainly on micro-organisms, with their role being enhanced by insects like mites, centipedes, sow bugs, snails, millipedes, springtails, spiders, slugs, beetles, ants, flies, nematodes, flatworms, rotifers and earthworms. These grind, bite, suck, tear and chew materials into smaller pieces, which make it easier for various microbes to move in and complete the decomposition process.

Of all the microbes that contribute to this breakdown, aerobic bacteria (bacteria that need oxygen to breathe) are the most important decomposers. They are very abundant, and most nutritionally diverse of all organisms that can eat nearly anything. These bacteria utilize carbon as a source of energy to keep on eating, and nitrogen to build protein in their bodies so they can grow and reproduce. Carbon-rich materials tend to be dry and brown, such as leaves, straw and wood chips.

While these bacteria can eat a wide variety of organic compounds, they have difficulty escaping unfavorable environments owing to their size and lack of complexity. Changes in oxygen, moisture, temperature and acidity can quickly make bacteria die or become inactive. When oxygen levels fall below 5%, the bacteria die and decomposition slows by as much as 90%. In this situation anaerobic micro-organisms (which do not need oxygen to breathe) take over. They produce a lot of useless organic substances, which are smelly and do not contain plant nutrients. In fact, they can produce things that are toxic to plants.

It is for this reason that it is very important to make sure that the right balance between aerobic and anaerobic bacteria is maintained. The easiest way of doing this is to get the right amount of brown (dead) and green (alive) material as described in the last chapter. As previously explained, if the balance is upset and there are too many anaerobic bacteria, which makes the heap smell and go bad, this can be remedied by adding more brown material and turning the heap.

There are a number of different sorts of bacteria at work in compost depending on the temperature of the pile, which changes according to the activity of the different bacteria. Actinomycetes, a form of bacteria which is similar to fungus and molds, create the earthy smell of compost as well as decomposing resistant materials like lignin and cellulose found in wood. This part of the composting process is also carried out by various sorts of fungi, which prefer the cooler temperatures during the final stage of composting.

BASIC PRINCIPLES FOR LOOKING AFTER YOUR MICROBES

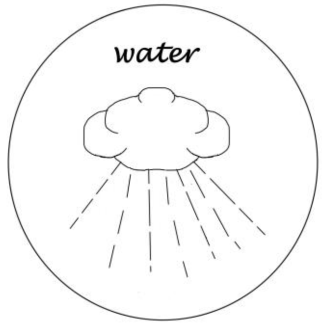
Encourage more microbes to come into your soil by:

Putting lots of organic matter into the soil to feed the microbial communities there. This will increase both the number and diversity of microbes.

Mulching the soil, especially when the weather is hot. This will keep the microbes cool and encourage them to reproduce more. This is particularly necessary in tropical climates and anywhere else where it is hot and dry.

Planting legumes, like beans, to encourage the microbes that fix nitrogen from the air.

Using EM and other similar products when you want a quick boost of microbes in your soil or compost heap.



My first experience of farming was in the mountains in India where there was a fair amount of rain during most of the year. During dry periods, which usually lasted for weeks rather than months, we used what was called the "*vaikal*" for irrigation. This was a little canal that ran along the top of the valley which had been built to divert water from a river so that it could be used for irrigation. Water from this canal was used by all the farms in the valley, who had developed a system of use that made sure that everyone in the valley got the water they needed. During dry times when we needed to irrigate, a hole was unplugged in the side of the canal to allow the water to run down the mountain onto our property. Here, with a series of earth dams, the water was channelled to where it was needed into our various gardens. It may sound rather rough and ready, but it worked well when most of the water we needed fell from the sky.

In Buddha Garden it is very different. Rain comes only at certain times of the year and is frequently unreliable and/or very heavy and destructive. If crops are to be grown consistently irrigation is necessary. Most days outside the monsoon we turn on our solar powered pump to get water. So far, when we have turned on the pump water has flowed, but more and more there are wells in Auroville that are running dry, especially in the hot season. So long as water flows when we press the 'on' button of our water pump it is easy to take it for granted for another day, and forget the fragile situation we are now facing with regard to diminishing water supplies. Water that is essential for all life on earth needs to be used for growing food in a way that recognizes this. We have to find different ways of using water more efficiently, whether – as in Buddha Garden – using AI technology, or as in another Auroville farm finding ways of collecting surface water, so that we do not have to rely entirely on ground water.

ABOUT WATER

Water is a neutral substance, virtually colourless, with no taste or smell and with a pH value of 6, which means that it is neither acidic nor alkaline. Water is called the 'universal solvent' because it dissolves more substances than any other liquid. Wherever water goes, whether through the ground, the air or our bodies, it takes along with it chemicals, minerals and nutrients that are valuable and necessary for life. Having this characteristic, however, also means that water easily carries pollutants, which can damage both the earth and ourselves.

The characteristics of water are:

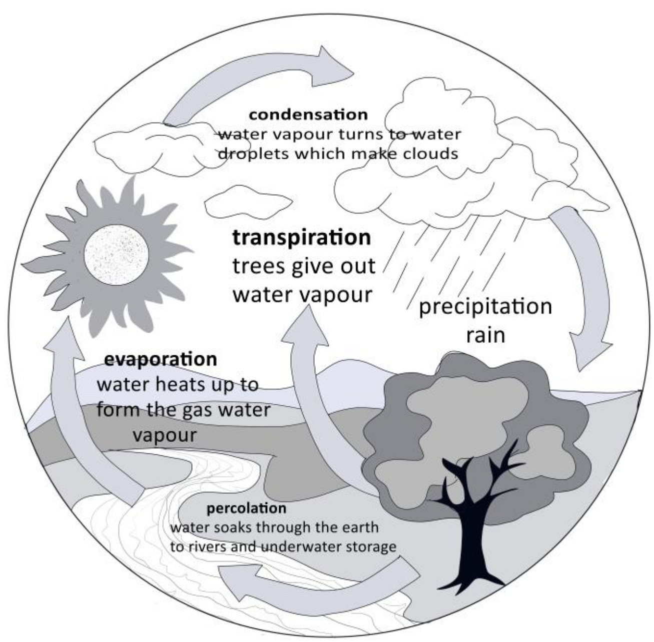
It is the only natural element that is found in all three states – liquid, solid (ice) and gas (steam) – at the temperatures normally found on Earth. The planet's water is in a constant state of flux, moving, interacting and changing from one form to the other.

It freezes at 32^{o} Fahrenheit (F) and boils at 212^{o}F at sea level. Water's freezing and boiling points are the baseline with which temperature is measured on the Celsius scale, where O^{o}C is water's freezing point, and 100°C is water's boiling point. Water is unusual in that the solid form, ice, is less dense than the liquid form, which is why icebergs float.

It has a high specific heat index, which means that water can absorb a lot of heat before it begins to itself get hot. This is why water is valuable as a coolant, for example in a car radiator. The high specific heat index of water also helps regulate the rate at which air changes temperature, which is why the temperature change between seasons is gradual rather than sudden, especially near the oceans.

It has a very high surface tension. In other words, water is 'sticky' and 'elastic' and tends to clump together in drops rather than spread out in a thin film. This is due to something called 'hydrogen bonding'. Water is composed of two hydrogen and one oxygen molecule giving it the chemical formula H_2O, although it is more helpful to think of it as H-O-H. The oxygen molecule in the middle holds the electrons so tightly that it has a little bit of negative charge, whilst the hydrogen molecules at each end have a little bit of positive charge. Since positive charges are attracted to negative charges, each water molecule in water is loosely bonded to the other in a giant network. Hence water is very cohesive, and this gives it a high surface tension and a boiling point at least 150 degrees higher that it would be without this effect. Surface tension is also responsible for capillary action that allows water (and its dissolved substances) to move through the roots of plants and through the tiny blood vessels in our bodies.

Water covers 70% of the earth's surface but we see only a small portion of it. The oceans contain 97.5% of the total water, the land 2.4%, with the atmosphere holding less than 0.001%. The annual rainfall for the earth is more than 30 times the atmosphere's capacity to hold that much water, which indicates the rapid recycling of water that occurs between the earth's surface and the atmosphere. This is known as the hydrologic (or water) cycle which takes place in the following way:



Water evaporates from the surface of the ocean or the land;

As the moist air ascends, it cools, and the water vapour condenses to form clouds;

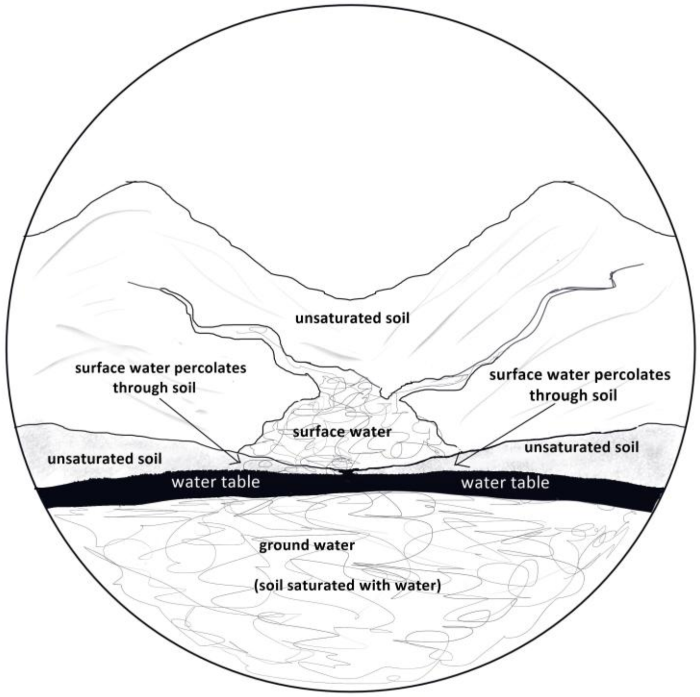
The clouds move around the globe until the conditions are right for droplets to precipitate from the clouds as rain;

Once the water reaches the ground, it either evaporates into the atmosphere again or it penetrates the earth to form ground water;

Groundwater either seeps through the earth into the oceans, rivers, streams and aquifers (underground water collection areas), or is released into the atmosphere through transpiration. The balance of the water is called 'run-off,' which empties into lakes, rivers and streams that carry the water to the ocean.

Ground water is an important constituent of the water cycle. It is the large portion of the rainfall that seeps down through the soil until it reaches rock material that is saturated with water. Water in the ground is stored in the spaces between rock particles. Ground water therefore moves slowly underground, generally at a downward angle (because of gravity), seeping through the earth and maybe eventually going into streams, lakes and oceans. There is an immense amount of water in aquifers below the earth's surface – a hundred times more water in the ground than in all the world's rivers and lakes. Some water underlies the earth's surface almost everywhere. This water may occur close to the land surface, as in a marsh, or it may lie many hundreds of feet below the surface, as in some desert areas. Water at very shallow depths might be just a few hours old; at moderate depth, it may be 100 years old; and at great depth or after having flowed long distances from places of entry, water may be several thousand years old.

Water seeps into the ground down to the many varieties of rock under the ground, some of which are able to hold water and some which cannot. This rock can also become broken and fractured, creating spaces that fill with water. Some rocks, such as limestone, are dissolved by water, which create large cavities under the ground that then fill with water. When a water bearing rock readily transmits water to wells and springs it is called an aquifer, into which wells can be drilled and from which water can be pumped. An aquifer is created when the water comes to a rock saturated with water thus forming a water table, as shown in the following picture:



As water is such an excellent solvent, it can contain many dissolved chemicals, especially when it has moved through many rocks and sub-surface soil. For this reason, ground water will often contain more dissolved substances than surface water. The ground is an excellent mechanism for filtering out things like leaves and soil, but it can also be a source of pollution. Underground water can get contaminated by bacteria from sewage, as well as chemicals such as pesticides, fertilizers and industrial contaminants. Such water can also become tainted by salt, either from the salt used on the roads to melt ice or because of the aquifer being pumped too dry and allowing salt water from the ocean to seep in. The physical properties of the aquifer play a large part in determining the extent to which contaminants from the land surface reach the ground water. However, because of the slow movement of ground water, restoration of a contaminated aquifer is a very slow process, which may require many years to achieve.

Vegetation is an important part of this cycle, and when it is disturbed, such as when forests are cut down, this can be very disruptive for the cycle. Without trees to soak up the water, it runs off the bare earth leading to excess flooding and erosion of topsoil. This has particularly dire consequences in tropical areas, where the amounts of water falling from the sky at any one time can be very large, and where the soil is more fragile and more easily washed away. If a lot of water runs off into the sea rather than percolating through the earth to underground aquifers, fresh water needed for all living creatures is lost.

Turbidity (cloudiness) in ground water is caused by the presence of suspended matter such as clay, silt and fine particles of organic and inorganic matter, as well as various microscopic organisms. It is measured according to how much light filters through the water sample. It may not adversely affect health but the water may need treatment. Ground water turbidity may be an indicator of surface contamination. In Buddha Garden we find that water turbidity increases during the hot season, when the water level in the well falls and it recharges more slowly. During the monsoon the water also becomes cloudier as the heavy rain filters through the earth and stirs it up. This can play havoc with the drip irrigation system that, despite filters, gets blocked up more easily.

Colour can be caused by decaying organic matter like leaves, or from metals like copper, iron or manganese. It may indicate that there are large amounts of organic chemicals requiring rigorous disinfection to make the water safe for drinking.

pH indicates the degree to which the water is alkaline or acidic. A high pH level (alkaline) in water has a bitter taste and causes encrustation in water pipes and water-using appliances such as heaters, dishwashers and laundry machines. It also requires more chlorination to make it safe for drinking. Low pH (acidic) water, on the other hand, will corrode or dissolve metals and other substances.

Odours may be indicative of pollution from waste discharges or sometimes from natural sources.

Taste may be affected by certain organic salts that produce taste without odour. Sometimes the so-called 'taste' is really an odour, although it is not noticeable until the water is taken into the mouth.

WATER USE

All over the world water usage is increasing at an alarming rate. The world's six billion inhabitants are already appropriating 54% of all the accessible freshwater contained in rivers, lakes and underground aquifers. By 2025 humankind's share will be up to 70%. This estimate reflects only the impact of population growth. If the consumption of water continues to rise at its current rate, humankind could be using over 90% of all available freshwater within 25 years, leaving just 10% for all other living beings.

On an annual global basis, 69% of all water withdrawn for human use is used in agriculture, mostly for irrigation. Industry accounts for 23%, and domestic use accounts for only about 8%. These global averages vary a great deal between regions. In Africa, for instance, agriculture consumes 88% of all water withdrawn for human use, while domestic use accounts for 7% and industry for 5%. In Europe, most water is used in industry (54%), while agriculture and domestic use take 33% and 13% respectively. More than 65% of the groundwater used in the US goes for agricultural irrigation, with industry being the second largest user and domestic consumption the third.

It takes an enormous amount of water to produce crops – 1 to 3 cubic metres yield just one kilo of rice, and 1,000 tons of water helps produce just one ton of grain. Land in agricultural use has increased by 12% since the 1960s, with pasture and crops taking up just over a third (37%) of the earth's land area. Not surprisingly, over-pumping of ground water by farmers is one of the main reasons for the lowering of water tables. Worldwide, the water used by farmers exceeds the natural replenishment by at least 160 billion cubic metres per year.

The need to stabilize water tables is urgent, because of the amount of over-pumping that happens in many parts of the world. If too much water is pumped out of a well this can eventually cause the well to yield less, and it may even run dry, especially when many wells are drilled into the same aquifer. Although falling water tables are historically a recent phenomenon, they now threaten the security of water supply and, hence, the food supply of 3.2 billion people. Beyond this, the shortfall – the gap between the use of water and the sustainable yield of aquifers – grows larger each year, which means the water level drop is greater than the year before. Underlying the urgency of dealing with the fast-tightening water situation is the sobering realization that not a single country has succeeded in arresting the fall in its water tables or stabilizing water levels. The fast dwindling water resources have not yet translated into food shortages, but if un-addressed may soon do so.

The Auroville bio-region is a good example of the process that is happening in many other places in the world. Since 1996, the water resources (hydrology and groundwater) team[2] has been monitoring the water levels and quality parameters over a 200 sq.km area, covering the Auroville plateau and its surrounding area. After the monsoons, the fluctuation of groundwater levels and tank water correlating with the rainfall is measured as well as the runoff into the sea. The data is compiled in a database that also includes sociological information. The collected information is processed in Geographical Information Systems (GIS) for further modelling, which provides a thorough and up-to-date tool for watershed management.

This research shows that there has been a tremendous decline in the level of the water tables – up to 45 metres over 30 years in some locations. There has also been an alarming increase of salinity in the groundwater, particularly in the main aquifer of the region. While the water levels are going down, the salinity levels are increasing. The salinity rates throughout the aquifer exceed the levels for safe drinking water, and in some areas exceed the levels for safe irrigation water set by the World Health Organization.

Research on the source of this salinization led to the surprising findings that the cause is not yet from sea water intrusion, but from several other factors. This includes upward leakage from an aquifer below and the input of brackish water into a large swamp, which then infiltrates the aquifer from above. It is expected that seawater intrusion into the ground water will occur sometime soon (it was estimated sometime between 2003 and 2020) because of the many wells and high extraction rates already in existence, which are unlikely to decrease. Already there are many wells in villages close to the coast where the water is too salty to use. If left unattended, it could endanger the entire south part of the watershed, from where Auroville extracts its water. The consequences of such intrusion would be disastrous, as water for irrigation and drinking purposes would become scarce in the local inland villages, and towns could see their main source of drinking water badly affected.

Everywhere it is agriculture which is most responsible for nearly three quarters of the pollution found in groundwater. Poor drainage and irrigation practices have led to saline build-up in about 12% of irrigated land worldwide, with a combination of salinity and water-logging affecting another third of land. Many of the world's most important grain lands are consuming groundwater at unsustainable rates. Collectively, annual water depletion in India, China, the United States, North Africa and the Arabian Peninsula adds up to a hefty 160 billion cubic metres a year – an amount equal to the total annual flow of two Nile rivers (figures taken from UN Food and Agriculture Organization).

The rapid increase in agro-chemical use in the past five decades has contributed significantly to the pollution of both surface and groundwater resources. Fertilizers and pesticides which have entered the water supply through runoff and leaching into the groundwater table pose a hazard to human, animal and plant populations. Some of these chemicals include several substances considered extremely hazardous by the World Health Organization (WHO), and which are banned or under strict control in developed

2 This work was originally carried out by the Harvest organisation within Auroville and has now been take over by the Auroville Water Group http://aurovillewater.in for the most up to date information. They collect and processes a wide range of data relating to ground and surface water in order to gain a full understanding of the complex water situation in the bio-region

countries. Studies on the Ganges river indicate the presence of chemicals such as DDT and endosulfan (as well as many others) in levels greater than recommended by international standards. Some of these substances have been known to bio-accumulate in certain fish and animals. When these are consumed by humans there is an increased risk of contamination, and a likelihood that the chemicals will persist in the environment for long periods of time.

Water enriched by agricultural soil nutrients leads to a condition called eutrophication in nearby lakes and ponds. The sudden availability of nutrients such as nitrogen, phosphate and potassium found in chemical fertilizers spurs the growth of aquatic plants and other organisms. In a short time, the water body becomes choked with vegetation and the oxygen level decreases. Decaying organic matter releases odorous gases, and partially decomposed matter accumulates on the river or lake-bed, thereby limiting the water's suitability for human consumption, as well as for other water creatures. A high level of fertilizer use has been associated with increased incidences of eutrophication in rivers and lakes in several of India's most important water bodies, such as the Hussein Sagar in Hyderabad, and lakes around Nainital in Uttar Pradesh.

So what can be done? To avoid water shortages that lead to food shortages requires a worldwide effort to raise water productivity. Land productivity is measured in tons of grain per hectare or bushels per acre, but there are no universally accepted indicators to measure and discuss water productivity. The indicator likely to emerge for irrigation water is kilograms of grain produced per ton of water. Worldwide that average is now roughly 1 kilogram of grain per ton of water used.

The first challenge is to raise the efficiency of water irrigation, since this amounts to 70% of world water use. Crop usage of irrigation water never reaches 100% simply because some irrigation water evaporates from the land surface, some percolates downward, and some runs off. When attempting to raise the water efficiency of irrigation, the trend is to shift from the less efficient flood-or-furrow system to overhead sprinkler irrigation or drip irrigation. The latter also raises yields, because it provides a steady supply of water with minimal losses to evaporation. A few small countries – Cyprus, Israel and Jordan – rely heavily on drip irrigation to water their crops. Among the big three agricultural producers – China, India, and the United States – the share of irrigated land using these more efficient technologies ranges from less than 1% in India and China to 4% in the United States.

Over usage of water is often the result of low water tariffs, which are often irrationally low, owing to their having being formulated in an era when water was considered an infinite resource. This is the case in the Auroville region, where farmers receive free electricity for pumping water. With the high cost of irrigation systems – and the possibility that they would get stolen – there is no incentive whatsoever for farmers to take measures to limit their water use. Aurovilian farmers have the possibility of obtaining resources for more efficient irrigation systems, but local farmers rarely do. As a result, they tend to take a more short term view of how to solve any water problems they experience.

In Buddha Garden, for instance, some years ago a French research student investigated our water use as part of his university study. He found that there were many ways in which we could use water more efficiently. This included simple measures like making sure that we use the sprinklers only when the tank is full, so that there is sufficient pressure for them to work properly and water the beds evenly. At the same time, we also changed our system so that all the beds could be watered independently or turned off if necessary. This was not cheap to do, and we were lucky to obtain funding for this work. Greater efficiency with water does not, unfortunately, automatically lead to an increase in production that could over the course of time pay for such improvements. For ordinary farmers, therefore, such expenditure would not be possible – unless it was financially supported by the government. This would involve charging for electricity for pumping and heavily subsidizing irrigation equipment to make it affordable for farmers. Politically, this would be extremely difficult to do in the present situation.

More recently, in the last two years, we have been involved in research which has shown that it is possible to both save water and increase production. This work was carried out in association with Heriot-Watt University in Edinburgh and Findhorn community in Scotland as part of their SCORRES program – Smart Control of Rural Renewable Energy and Storage. The aim of the research in Buddha Garden was to compare the working of a 'smart' watering system with our normal manually operated irrigation system. Comparisons were made about water usage, plant growth, plant production and soil health using a number of different parameters that were evaluated using soil tests.

The research was carried out in three places in Buddha Garden: the Souryan garden which has been in existence since the farm started 20 years ago, Le Jardin which has been in existence for 14 years, and New Horizon where we set up vegetable beds two years ago when the land was finally brought under Auroville's control.

In each garden there were three beds allocated to the research. The middle of the three beds was the 'research' bed where the smart irrigation system was set up. It consisted of a series of soil sensors that sensed how much moisture was in the soil, which were linked up by wireless signal to the solar electricity system – an essential part of the hardware. When the moisture level went down to a certain level, the sensors detected it and a wireless signal was sent to turn the irrigation system on. Once the correct soil moisture level that provides optimum moisture for the growing plants was reached, the sensors sent another wireless signal to the solar system that then turned the irrigation system off. This went on throughout 24 hours.

Initially, the amount of water being given to the plants via the smart water system was based on previous research carried out by Buddha Garden. Over the years, data had been collected by Buddha Garden that showed the amount of water needed by different sorts of vegetable plants at different times of their growth. The smart water system was set up according to this data and other general variables that affected plant growth such as temperature and rainfall. As time passed, the computer began to control the irrigation more accurately in the context of all the relevant variables. As the system got smarter, the plants received the optimum irrigation they needed for optimum production. The system became more precisely aligned with the water needs of the growing plants.

This system both reduced the amount of water used, compared to our manual system, as well as increasing production. This was easy to see when comparing the research and control beds in each of the three gardens, where plants in the research beds were obviously larger than those on the control beds. As a result, local farmers were very interested in this system. Not only did it save water, but it also saved them time watering. As it would improve their production they had a means to pay for the system. Development of the system continues with a focus on how it can be controlled by a mobile phone, rather – as in our case – our internet connection. They are also enlarging the research to include other crops like fruit trees and to carry out some of the research in China.[3]

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[3] https://www.facebook.com/...smart-control-of-rural-renewable-energy-and-storage.../17...

http://scorres.macs.hw.ac.uk/

What is needed now is a new way of thinking about water use. Reducing water use to a level that can be sustained by aquifers and rivers all over the world involves a wide range of measures not only in agriculture but also throughout the economy. Generally, as water becomes scarce, it needs to be priced accordingly so that consumers understand its value. The advantage of higher prices is that it affects the decisions of *all* water users. Higher prices encourage investment in more water-efficient irrigation technologies, planting more water-efficient crops, adopting more water-efficient industrial processes, and using more water-efficient household appliances. At the same time, prices must not be so high that it forces farmers to stop farming. Or that poor people end up paying disproportionately more for water than everyone else.

In many cities of the world, and especially those where water scarcity is a daily problem, it may be time to rethink the typical urban water use model where water flows into the city, is used once, and then leaves the city – usually becoming polluted in the process. This 'flush-and-forget' model that dominates urban water systems today will no longer be a viable option in the future, especially in regions facing extreme water scarcity. If recycled efficiently, water can be used indefinitely in cities and by industry. Some cities are beginning to do this. Singapore, for example, which buys its water from Malaysia, is starting to recycle its water in order to reduce this vulnerable dependence. One of the less conventional steps is to shift from outdated coal-fired power plants, which require vast amounts of water for thermal cooling, to wind power – something long overdue in any case for reasons of pollution and climate disruption.

In Auroville, during 2007, Harvest carried out a pre-feasibility study for the development of a water strategy for the bio-region. This report examines in detail the water problems of the area and then suggested a number of tactics for dealing with them. An integrated water management approach that limits the use of ground water and recycles water wherever possible needs to be used. Later in the year Auroville hosted a meeting of all those in the bio-region concerned with water management. It was clear that what is needed is a concerted approach by all the authorities concerned with water use, but that it will not be easy to manage. It is hoped that Auroville will provide the leadership necessary for this to come about.

While the provision of water is increasingly a global problem, there have been areas of the world which support a large population where water conservation has been carried out using low tech methods for many hundreds of years. A famous study by F. H. King[4] in the early 20th century examined the farming practices in China, Korea and Japan, and found that water conservation was an important part of their strategy. He states:

> *'To anyone who studies the agricultural methods of the Far East in the field it is evident that these people, centuries ago, came to appreciate the value of water in crop production as no other nations have. They have adapted conditions to crops, and crops to conditions, until with rice they have a cereal which permits the most intense fertilization and at the same time the ensuring of maximum yields against both drought and flood. With the practice of western nations*

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4 *From 'Farmers of Forty Centuries or Permanent Agriculture in China, Korea and Japan' by F H King DSc. Published New York: Harcourt, Brace 1911, Reprinted by Kessinger www.kessinger.net*

in all humid climates, no matter how completely and highly we fertilize, in more years than not yields are reduced by a deficiency or an excess of water.

It is difficult to convey, by word or map, an adequate conception of the magnitude of the systems of canalization which contribute primarily to rice culture. A conservative estimate would place the miles of canals in China at fully 200,000, and there are probably more miles of canal in China, Korea and Japan than there are miles of railroad in the United States. China alone has as many acres in rice each year as the United States has in wheat, and her annual product is more than double and probably threefold our annual wheat crop, yet the whole of the rice area produces at least one and sometimes two other crops each year.

The selection of the quick-maturing, drought-resisting millets as the great staple food crops to be grown wherever water is not available for irrigation, and the almost universal planting in hills or drills permitting inter-tillage, thus adopting centuries ago the utilization of earth mulches in conserving soil moisture, has enabled these people to secure maximum returns in seasons of drought and where the rainfall is small. The millets thrive in the hot summer climates; they survive when the available soil moisture is reduced to a low limit, and they grow vigorously when the heavy rains come. Thus we find in the Far East, with more rainfall and a better distribution of it than occurs in the United States, and with warmer, longer seasons, that these people have with rare wisdom combined both irrigation and dry farming methods to an extent and with an intensity far beyond anything our people have ever dreamed, in order that they might maintain their dense populations.'

The strategies described grew up slowly over the centuries, and as is normal with sustainable food growing a number of different strategies were employed to use water in the most effective way. While water deficiency is now a global problem, with solutions needed at a national and regional level, sustainable food growing practices are an important part of the solution – even though they may not necessarily be supported politically. Sustainable farmers can only do so much individually. Eventually the world will have to wake up to this problem, and the necessary strategies at national and regional levels will have to be implemented and supported.

Or there will not be enough food for everyone on the planet.

BASIC PRINCIPLES OF LOOKING AFTER YOUR WATER

Water is crucial to growing food, so it is necessary to make sure that **sufficient water will be available** when you need it. How much food can be grown is dependent on what water resources are available.

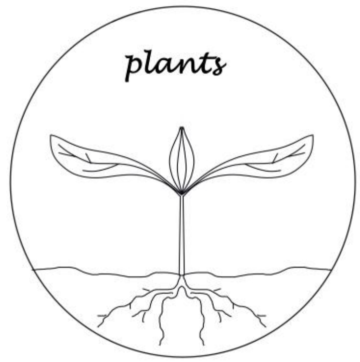
It is essential to use water with awareness even if you think you have all you need. This is one area of food growing where you really do need to 'think global, act local'. Ways of using water effectively might include:

Making sure that **whatever irrigation system is used works properly.** Leaks have to be plugged and drippers made to drip at the correct rate. For us this means mending the holes made by small animals biting into the pipes looking for water, and adjusting the drips, although this is difficult as the drippers are not very accurate.

Planting water efficient crops – for us in Buddha Garden this means using local plants that can cope with the climate, as well as making sure that where we do irrigate as many plants as possible benefit. We have, for instance, planted vegetables between some of our banana and papaya trees so that we get fruit and vegetables with no extra water use. Depending on the water available, in different parts of the farm different kinds of crops can be grown.

Planting trees and earth bunding to prevent water runoff and a better percolation of water to the underground aquifer. This is particularly important in tropical hilly/mountainous areas, especially where the rain is very heavy and leads to soil erosion.

Supporting necessary action with local communities, and over a wider geographical area to conserve and manage water resources sustainably.



BANANA PLANTS IN BUDDHA GARDEN

Dancing in the breeze
Floppy eared elephant's heads
Some quite small, some growing tall,
From out of their mulched beds.

Butterflies dance amongst
Your shady leaves
The sunshine enlightens
The stunning green aura.
Makes me feel at peace.

Magnificent red flowers, ideal
For mothers feeding babies their milk
And leaves make crazy giant platters
Perfect for special thali
Yummmmmmmmmmmmmm

Most of all I love your bananas
Perfect with honey and ice cream.

This poem was written by a volunteer (who wishes to remain anonymous) and I think sums up the many levels on which we need, use and enjoy plants.

PLANT CHARACTERISTICS

Plants are the basis for all our food, whether we eat them directly or eat the animals that get their sustenance from them. They also play a major part in two major cycles, the carbon and nitrogen cycle, both of which are essential to the overall health of the Earth (see appendix 2.

The essential characteristics of plants, as compared to other living beings, are as follows:

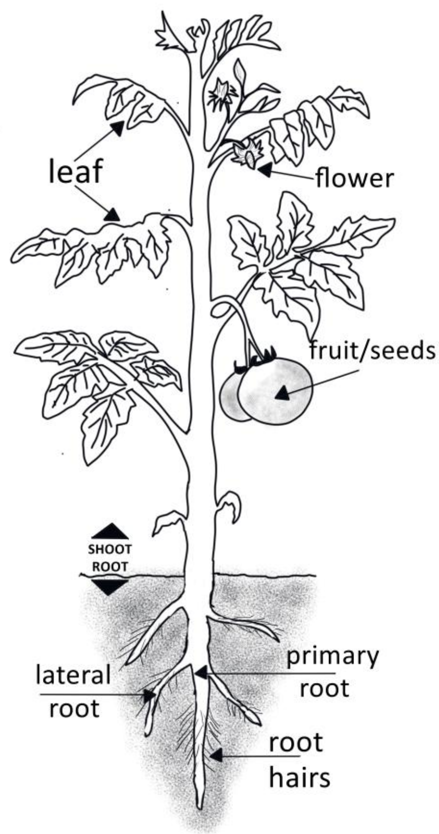
Generally, they are rooted in one place and do not move on their own – while some plants may be moved around by wind or water, they cannot voluntarily decide to move to a particular place like animals and most other living organisms. Plants contain a special substance called chlorophyll (which is what makes them green), which allows them to make all their own food.

During the day plants take in carbon dioxide and give out oxygen. This process is part of photosynthesis and is vital for the survival of life on Earth (see the carbon cycle in appendix2).

At the cellular level they have cell walls, but also certain other structures that are seen only in plants.

Plants have a minimal ability to sense. In fact, research shows that they are able to sense, but that their responses are very subtle and not always immediately obvious. Often people who work with plants find that it is possible to develop a relationship with them that is positive both for them and for the plants.

PLANT STRUCTURES



The basic parts of a plant are:

The Root: Defined as the portion of the plant beneath the soil, it is through the roots that plants absorb water from the soil, and with the help of soil bacteria absorb the necessary minerals that the plant needs to grow. Since this process takes place through the delicate hairs on the roots, when handling plants it is very important to treat the roots very gently and to disturb them as little as possible. The root also helps to anchor the plant into the ground, and can act as a storage place for food for those times (perhaps during certain seasons) when the plant cannot make its own food. We take advantage of this ability in growing root crops like potatoes and carrots.

The Shoot: The shoot refers to all parts of the plant structure above the soil and includes stems, leaves, flowers and fruits.

The Leaf: The leaf is an important part of the shoot that participates in the process of both respiration and plant food production (photosynthesis).

HOW PLANTS BREATHE

Like humans, plants need air to survive. The air surrounding the Earth is a mixture of several different gases. The three most important gases that are needed for survival are oxygen, nitrogen and carbon dioxide. Oxygen makes up about 21% of the air, nitrogen 78%, and there is a small amount of carbon dioxide in the air – 0.03%. There are less than 1% of other gases that get mixed by the wind and cover the Earth in a five to six mile deep layer called our atmosphere. This mixture of gases is not all we breathe, as there are other substances in the air, like pollens, dust, smoke, salt particles, water vapour, chemicals, spores, bacteria and viruses.

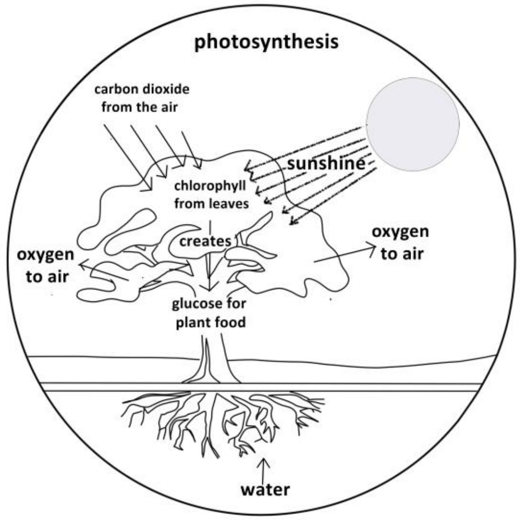
Humans cannot survive for more than a few minutes without the oxygen contained in air. During the process we call respiration we breathe air into our lungs. In the lungs there is an exchange of gases with oxygen from the air released into the body, and carbon dioxide from the body is released into the lungs. When we exhale, the carbon dioxide, mixed with water vapour from the body, is released.

The breathing process in plants is rather different, although the leaves on a plant act very much like lungs. Thousands of microscopic openings called stomata are located largely, but not exclusively, on the underside of leaves. Each stoma is surrounded by special cells that regulate the size of the opening so that air can pass in and out of the plant. Plants use these specialised cells to breathe in oxygen and exhale carbon dioxide very much like humans. These cells also play an important part in water regulation, as when it is very dry the stomata close to keep the plant from losing too much moisture. This is what happens when we describe plants as 'wilting'; they are conserving what water they have inside the plant. In Buddha Garden we often see our plants doing this in the middle of the day, especially during the hot season. Some people interpret this as the plant showing that it needs more water, which is not necessarily the case. We find they often recover spontaneously later in the day or evening when it is cooler. Only if the wilting continues beyond the very hot times do they need extra water.

HOW LEAVES MAKE FOOD FOR THE PLANT

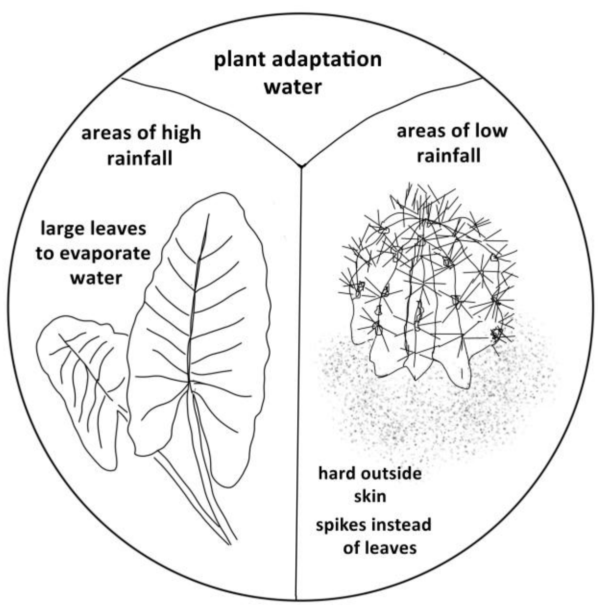
The most important function of leaves, both for the plant and for humans, is the process of photosynthesis, which literally means "to put together with light". The leaf contains cells which contain green-pigmented chemicals called chlorophyll that absorbs sunlight. The plant absorbs carbon dioxide from the atmosphere, and with the sunlight energy produces sugar which feeds the plant. In the process oxygen is generated which is released into the air. The plant's root and the shoot are dependent on each other, as the latter cannot absorb minerals while the former cannot photosynthesise, two functions which are essential to the plant's life.

Through this function, the plants and trees around us help to balance the gases in our air. Humans breathe in oxygen and expel carbon dioxide, while during the day in the presence of light plants absorb in carbon dioxide and release oxygen. To maintain the healthy composition of air, and ultimately for all living beings on earth that rely on this air, this process needs to be very carefully safeguarded.



PLANT ADAPTATION

Plants adapt to where they are living, and the size of leaves is often a good indicator of the climate to which they are adapted. Plants that live in areas of high rainfall, such as the tropical rain forest, often have huge leaves as they need to get rid of large amounts of water through evaporation. Plants that live in dry areas have small leaves to preserve as much moisture within them as possible. Desert plants usually have thick, round leaves that reduce the surface area and thereby the evaporation rate. They also have a waxy covering, which inhibits evaporation. Desert plants like cactus have spikes rather than leaves.



THE LIFE CYCLE OF THE PLANT – SEED PRODUCTION AND VEGETATIVE PROPAGATION

SEED PRODUCTION

Plants go through the following stages in their life/reproductive cycle.

Germination is when a new plant starts to grow from a seed. In Buddha Garden all our plants, apart from white radish and some varieties of spinach, start life in the nursery where they can be looked after in a protected environment. Here they are sheltered from cats and dogs, various pests, as well as the extremes of the weather, which in our case is very hot weather rather than frost. Our nursery is covered with a large piece of polythene that allows the full spectrum of light to come through, but protects the small seedlings from the very heavy rain, which is especially necessary during the monsoon. In the summer the nursery is covered with a shade net to protect the plants from the sun. The protection seeds require depends on the climate, as well as local conditions like what animals are around. We have had to make some special protective covers for some of our trays to stop the squirrels eating the trayfuls of sunflower seeds, which we put out to grow sunflower microgreens.

For different plants, different conditions are necessary for germination. Maybe a particular temperature is needed or a certain soil moisture content is required. Lettuce, for instance, will not germinate well above 23 degrees C, so if we want to grow it in conditions above that temperature we have to cool the soil in which they are planted. We do this by watering the soil and the seeds with iced water. Since they germinate within six hours, this is enough to get most of the seeds to germinate when temperatures are higher. Generally, all seeds like to be kept damp until they germinate, and seeds generally enjoy being watered little and frequently. Too much water will make them rot or invite fungus on them.

In many places it is possible to buy various sorts of compost specially developed for germinating and growing small seedlings. In our case we make our own mixture, which consists of:

Compost to help the seed grow.

Sieved soil which creates a mixture with a good texture that is loose enough so that the roots can obtain oxygen. This also stops the mixture from being too rich, as this makes the seedlings grow too quickly. When this happens, they find it hard to survive when planted into ordinary soil.

Coconut fibre or any other material that holds water and stops it drying out too quickly. The coconut fibre that we use is the waste left over from making coconut fibre string. It used to be extremely cheap, but since coconut fibre is now being imported in many European countries as a substitute for peat, it is much more expensive.

The final mixture, which we call 'nursery mixture', is composed of one third each of sand, compost and coconut fibre, which is first sieved and then mixed together thoroughly.

Very small seeds, such as those of tomato, chilies, brinjal, lettuce and basil, are first planted in flat trays. Seeds are sprinkled thinly over the top of the soil, and then covered with a small layer of nursery mixture. When the plants have grown 2–3 leaves they are carefully transplanted into small pots in trays, disturbing the roots as little as possible. Larger seeds like beans and ladies finger we plant straight into the pots filled with the nursery mixture. In many places it is possible to buy ready-made cubes of material into which seeds can be sown and left until they grow. The advantage of these is that the cubes can be put straight into the growing bed with no disturbance to the roots.

Depending on where you live there are many sorts of nursery growing systems of all sizes for both amateur and professional use. Some automatically water the seeds and/or regulate the temperature at which the seeds are kept until they grow. In our nursery we have set up an automatic watering system which we designed from scratch.

We plant very few seeds straight into the soil. Towards the end of the year when temperatures are lower we grow radish, and these have to be planted straight into the soil as once growing they cannot be transplanted. When we are short of nursery space we sometimes plant bean seeds straight into the bed, but make sure that we also plant a few in the nursery as well at the same time. Then if any of the seeds do not grow we can plant these seedlings into the spaces.

Growing from seedling to adult plant: To grow well, all plants need to be planted in a fertile soil with enough air, light, water, and to be in the right temperature.

When I first came to Buddha Garden, all our seedlings grew under nets for the first few weeks of their life on the vegetable beds. This was mainly to protect them from insect pests, but in the hot season it also protected them from the very hot sun. As the soil has improved and the plants have grown stronger this net protection is now rarely necessary, but it protects against animals uprooting the seedlings or eating the harvest, rather than insects. Very occasionally it still happens, but only at certain times of the year when food for the insect or animal is short because of exceptional conditions.

We plant seedlings in a way that disturbs the root system as little as possible, and put them in a situation (with plenty of compost and water) that allows them the best possible start to grow into productive plants. As soon as the plants are replanted they are watered. This is very important because it washes the soil next to the roots, which then find it easier to obtain the nutrients from it. In very hot weather we dig a hole and put water in the hole before we replant the seedling, as this helps more of them survive.

The main work we carry out with the plants during this period of their growth is to keep the weeds down, so the plants have space to grow. We remove the weeds manually, and also cover the soil with some sort of mulch. This keeps out the light from the weeds, which inhibits their growth, as well as helping to retain moisture and bacterial activity in the soil. We used to use rice straw for this purpose. It worked wonderfully, but was expensive, as in this part of the world it is used as cow food and was rarely organically grown. We now use leaves, which have the advantage of being free (although we have to pay to have them collected) as they are someone else's waste. They do, however, have a tendency to blow off in high winds, and in some weather conditions can break down rather too quickly, leaving the soil uncovered. As they grow some plants are regularly watered with compost tea or liquid manure to feed them while growing.

From time to time we talk about ways to keep down the weeds, such as using black plastic or some other form of weed mat that completely cuts out the light and therefore stops the weeds growing. We are totally opposed to black plastic, as it would heat up the soil and disposal of the used plastic would be a problem. In some places it is possible to purchase a weed mat that is certified organic, and over time (usually quite a long time) eventually composts itself into the soil. This does not seem to have reached the Indian market yet. So, we carry on weeding manually to ensure enough space for our vegetables to grow.

Flowering: The flowers come when the plant is ready to reproduce. If conditions are poor, however, the plant may either not produce flowers or produce flowers very quickly, so that seeds are produced quickly before conditions deteriorate. We noticed this happening to some of our plants that survived the 2011 cyclone. If plants flower early we find this can be because of unexpected climate conditions or an indication to us that the plants need more nutrition.

Pollination of the flower: Flowers produce male cells called pollen and female cells called ovules (eggs). The pollen has to get to the ovules for the plant to produce seeds from which new plants will grow. Plants have evolved in ways that allow them to live in symbiosis with insects and the wind, which act as the main pollinators. In some plants that need insects for pollination, the flowers have colourful petals and sweet-smelling nectar to attract them. The plant's pollen then sticks to the insects and they carry it to the next plant they visit. (There is more about this in the next section about insects.) Some plants are pollinated by the wind. These plants have small petals and stamens (which contain the female ovule) outside their petals so that the pollen can easily be blown off by the wind. Wind-pollinated plants often produce large amounts of light pollen that can be carried for long distances. Fertilisation occurs when the pollen and ovule fuse together and eventually produce a seed.

To ensure reproduction by plants, it is essential to understand this process and make sure that the right conditions are available for pollination to take place. For some time, we found it very difficult to get fruit from our passion fruit. Then we found out that they are pollinated by carpenter bees that live in old wood. We have therefore left quite a lot of old wood near the plants to encourage the bees to come and live there. If they do not, we can still pollinate by hand, although as passion fruit creep all over the place some of the flowers can be in rather inaccessible places.

Once fertilization has taken place, then the flower withers and the vegetable or fruit is formed. Usually we pick and eat the fruit/vegetable before seeds are formed.

Seed production is a three-stage process. First, the flowers have to be fertilised; then the seeds have to grow and mature; then they have to ripen. During this latter process the seed pod will become dry and will often change colour. In lady's finger, for instance, the pod has to dry and the seeds turn green on the plant before they are ready for collection and use. We eat ladies finger before they reach the last stage of the seed producing cycle, so to get our own seed we grow special plants for producing seed in the Seed Garden.

Seed dispersal: To ensure that plants have enough space to grow, seeds must be dispersed away from the parent plant. Since plants cannot move, they must use other methods to make sure the seeds are dispersed:

Animals eat the fruit and then excrete seeds far away from the parent bush. For some seeds this is a necessary process before the seed germinates. Plants that depend on this method of seed dispersal have fruit that attract the animals by colour or smell.

Seeds can be dispersed by explosion. Peas, for instance, have a seedpod that dries and splits, flinging the seeds over a wide area.

Seeds can be dispersed by the wind. Grasses have fine, light seeds with 'whiskers' that are blown long distances by the wind.

Seeds can be dispersed by water. Coconuts have a thick outer coat and are designed to float in water.

Once the seeds have been dispersed they are ready to grow into new plants, and the cycle starts all over again.

VEGETATIVE PROPAGATION

Plants have another asexual way of reproducing which is called 'vegetative' reproduction. This mode produces clones of the parent plant and can be a useful back-up in case the forms of sexual reproduction fail. This can take place in the following ways:

Fragmentation: a process by which several pieces of a severed plant can regenerate into whole new plants.

Tubers: These are fleshy underground food storage structures which are basically enlarged parts of the stem. Buds form on the tuber, each of which can grow into a new plant.

Runners: These are slender horizontal stems that spread outward from the main plant. New plants can develop from nodes located at intervals on the runners; each node can give rise to new roots and shoots.

Bulbs: These are roughly spherical underground buds with fleshy leaves extending from their short stems. Each bulb contains several other buds that grow into new bulbs, and eventually new plants.

Again, the best way of using these processes to propagate the plants will depend on the plant variety.

SEEDS AND BIODIVERSITY

Before the days of seed companies, which wasn't so very long ago, farmers saved seed from their crops, often taking them from their best plants to use the following year. Compared to today there was a very wide diversity of food crops adapted to local conditions.

Increasingly, however, the global food supply has become dependent, both on a small number of species and a smaller number of varieties within that species. Now a mere 24 food plants account for 75% of all plant calories and 90% of arable land cultivated. This list includes six grasses – rice, wheat, corn, barley, oats and sorghum; four legumes – soybeans, peanuts, common beans and peas; two sugar crops – sugarcane and sugar beets; two tropical tree crops – bananas and coconuts; four starchy roots – potatoes, sweet potatoes, cassava and yams; five fruits – tomatoes, grapes, apples, oranges and mangoes; and two vegetables – cabbages and onions. (This is an agricultural calorie list, and does not recognize the extremely rich vitamin and mineral sources found in low-calorie vegetables and fruits. Also this list does not recognize the important regional foods of the world.)

There are many reasons for this loss of biodiversity, but one is the increasing use of hybrid and genetically modified (GM) seeds.

HYBRID SEEDS

Genes are organelles (a specialized structure within a living cell) within the seed and the plant, which carry information about the characteristics of the plant and how it will grow. When a plant is fertilised the male and female genes combine and are carried in the seed. Traditionally crops were 'open pollinated', which meant that the pollen could come from a large number of different plants, so that it was difficult to predict how plants would produce from year to year. If the climate was very variable, however, plants with varying characteristics were an asset. Whatever the weather, probably at least some of them would have characteristics that would enable them to survive.

Over the last fifty years or so various methods have been used to manipulate plant genes to improve crop species in more predictable ways. One method is to create a hybrid seed, which is a cross between two varieties of the same plant. This happens from time to time in nature, but in 1920 the first human plant hybrid was created using maize. This process has since extended to vegetables and flowers, and more recently to rice and some forage crops. It is carried out in the following ways:

Two 'inbred' lines of the two varieties are produced. This is done by pollinating the flowers by hand from the same plant.

Once the two inbred lines are established, the two varieties are cross-pollinated to produce what is known as a first generation or 'F1' hybrid seed.

Seeds produced in this way have what is known as 'hybrid vigour', which means that they produce more and uniform crops, all at the same time. The hybrid process can also be manipulated to create plants that produce crops of a particular type – extra red tomatoes or papayas with a long shelf life. Often this means, however, that the plants either need a very good soil and/or a lot of fertilizer. If seeds of hybrid plants are saved they will not have the same characteristics as the parent plants. The two different varieties combined in the F1 hybrid seeds segregate out in the offspring. In other words, the superior qualities of the F1 hybrid disappear in the next generation of plants, which 'revert to type' or go back to the original two varieties. The development of hybrid seed is done almost exclusively by seed companies for the practical reason that they have the expertise for the work, and the means to maintain appropriate in-bred lines in an economical way. Hybrid seed production has prevented farmers from saving and replanting seeds, making it necessary for them to purchase seeds every season.

As more and more farmers use hybrid seeds the irony is that they have a tendency to eliminate the varieties from which they have been derived. Hybrid varieties yield better than the varieties from which they are derived, and very often displace them in farmers' fields. Once a displaced variety is no longer planted, its genes are lost to future generations unless it is conserved, usually in a seed bank collection or as an heirloom variety. Many of these heirloom varieties taste better, cook better, or possess other unique characteristics that make them good for a particular environment, but they lack the productivity that mechanized farming demands in modern agriculture.

In-breeding – which happens when both the male and female pollen comes from the same plant – intensifies any weakness in the plant. Initially hybrid seeds may be more vigorous, but if there is a build-up of susceptibility to disease in the two inbred lines from which they are derived, this can have serious consequences. A particular weakness in the genetic stock of maize used to produce hybrid seeds in America made the plants susceptible to a fungus disease. During a damp 1970 summer, the disease spread widely in America with disastrous results for farmers who saw all their corn rotting in the field. Eventually new hybrid strains without this genetic weakness were bred, but not before many farmers had gone bankrupt.

Hybrid seeds were an important part of the 'green revolution' in India. This led to farmers using high-yielding hybrid seeds, chemical fertilisers, pesticides and weed-killers. While the revolution averted famine, it damaged the environment. This has included damaging the soil, because of fertilizer overuse as well as problems with water pollution and lowering of the water table. More worrying is that the Green Revolution has run out of steam, and the productivity gains are tapering off with more and more fertilizers needed to keep the same level of production.

GENETICALLY MODIFIED (GM) SEEDS

In recent years, genetically modified seeds have been seen by some as the answer to the problems of the faltering Green Revolution. Hybrid seeds use only the naturally occurring genetic material of the two varieties of crop from which they are derived. By contrast, genetically modified plants can be created using genetic material from a range of living beings. This makes it possible to create 'designer plants,' which would never occur through natural means. For example:

To stop a range of pests from attacking cotton, genes from a pest-paralyzing bacteria were put into the plant's genetic material. The so-called 'BT Cotton' was not therefore attacked by pests and did not need to be sprayed with insecticide.

Drought-resistant maize could be created by putting genes from a cactus into the maize plant.

Soya bean has been genetically modified to resist certain weed killers, so that a farmer can spray the whole crop knowing that the weeds will all be killed but the soya plants will survive.

This is a new technology, that some farmers and governments have taken to with great enthusiasm. Other groups, who are equally concerned about this new technology and think that until research can show that it is totally safe, both for individual humans and the environment, think it should be used with some circumspection. This has led to fierce arguments as to whether GM crops are a good or bad thing – something which scientists are not agreed upon. Some of the questions and arguments for and against GM seeds are as follows.

Will there be health benefits?

YES: GM products can be created, which will have characteristics like low calorie wheat or a longer shelf life and will be safer to eat because they will contain fewer pesticide residues. GM foods will have even greater benefits for the world's poor because crops could be genetically modified to add vitamins and minerals. One of the most promising GM products is "golden rice", which can stimulate humans to generate vitamin A – important in those developing countries (like India) where vitamin A deficiency causes a substantial number of cases of blindness. Eventually, it is thought, GM plants will serve as environmentally friendly 'factories' that mass-produce useful substances such as pharmaceuticals and vaccines.

NO: GM foods may introduce new allergens, and putting bacteria into plants may introduce new antibiotic resistant bacteria into human bodies. At present it is very difficult to prove whether this new technology is safe for humans, or not, as the technology is too new to have carried out the necessary long-term studies.

Will GM crops benefit farmers?

YES: GM crops will benefit farmers with crops genetically engineered to resist pests. Growers will be able to avoid losses brought about by pests and bring their produce to market at less cost. Weeds will be easier to control with GM crops that are resistant to a single broad-spectrum herbicide. Farmers only need to use a single weed-killer rather than multiple kinds, and they may have to make only a single application rather than several.

NO: GM crops are developed by large companies that then take out patents so that others cannot use the seed. This means that farmers will have to continue paying money to these companies if they want to go on using the seed. GM crops might prove too expensive for poor farmers in developing countries, thus further widening the gap between the rich and the poor. GM plants might need higher inputs so that farmers are not better off despite higher crop yields. Even if farmers in developing countries do not grow GM crops, they could still be hurt by them. GM technology could enable the industrial North to raise crops it previously imported from the developing South. GM crops will also make us more reliant on vast monocultures, which are more vulnerable to lethal attacks by disease and pests. This has often happened in India, where farmers growing BT cotton have had their whole crop wiped out by a freak climatic event. This leaves the farmer with huge debts (for the seed and all the other things like fertilizer necessary to grow the seed), and many have committed suicide as a result.

Will they harm the environment?

YES: GM technology is a nascent uncontrolled experiment with unknown consequences for surrounding ecosystems. One big worry is that GM crops could harm other wildlife. Mosquitoes eventually became tolerant to DDT and there is the possibility that insects could become 'super bugs' resistant to pesticides engineered into GM crops. There is also the possibility that 'super weeds' could evolve that have become immune to a broad-spectrum weed killer, after crossing with and assuming the herbicide-resistant gene from a closely related GM plant. GM crops themselves can become weeds, such as in Canada where GM herbicide-resistant canola plants have invaded nearby wheat fields. There is also the worry that viruses could evolve with resistance taken from GM crops, and then transforming into entirely new strains that could infect a whole range of plants, animals and humans that were previously unaffected.

NO: If GM crops have resistance to pests and diseases built into them, this means that greatly reduced amounts of pesticides will be needed. To reduce or eliminate cross pollination between GM crops and other plants and insects, farmers can create buffer zones of conventional crops around GM fields to give harmful insects something to feed on, and thereby reducing the selection pressure to adapt to the GM plant. Buffer zones would also deter cross-pollination and provide a refuge for harmless and beneficial insects.

Does genetic modification go against nature?

YES: Nature has taken millions of years to effect genetic change. What right do we have to make changes so quickly over the course of a few years? Do we have the wisdom to substitute human for natural selection or to play God? Many argue we do not and that such acts are immoral. For some, GM technology flies in the face of cherished principles about the relationship between humanity and nature. For others, such pursuits offend deeply held religious beliefs.

NO: Genetic modification could not be more natural. Plants (and animals) genetically modify themselves all the time. That is the basis of evolution. We have been genetically modifying plants (and animals) for millennia. That is the basis of agriculture.

Modern GM methods are simply more precise. Whereas traditional plant breeding involves thousands of shared genes every time two plants are crossed, GM technology allows, if desired, for the exchange of a single gene between plants. GM procedures are also much faster. In months or years, molecular scientists can accomplish the same degree of alteration that might have taken nature millions of years to achieve.

Is it all about profits for the GM seed companies?

YES: GM seed firms invest heavily in research and development, and naturally they want to recoup their investment. In their rush to secure patents and reap profits, big biotech firms are deliberately over-promoting the benefits of GM technology and underestimating possible health, socio-economic and environmental hazards.

These companies are also concentrating their efforts in high-volume crops, such as soybeans, corn and cotton, and not in crops that might help feed the billions of people who live in poor countries. A World Bank report in 1997 found only four "coherent, coordinated" GM research programmes on developing-world crops at the time. In 1998, the top ten seed companies controlled an estimated 30 to 40% of worldwide seed sales, which reach $45 billion a year.

NO: While GM companies are concerned about profits, their products are primarily driven by research and innovation. This is the only way to meet the world's increasing needs for food and medicines in a rapidly shrinking and increasingly scarred natural environment. Innovation requires costly and time-consuming research and testing, which will only happen if it is paid for. The best way to ensure it is paid for is through intellectual property protection. Patents should operate worldwide because markets are increasingly global in nature.

The result of this innovation will be GM crops that will offer our best chance to adequately address the challenge of feeding the increasing world population. GM crop farming holds out greater promise than conventional farming for boosting production on the same piece of land, and of raising crops where none could grow before, such as in saline soils. Increasing yields with GM crops is the only way of making marginal lands productive and staving off widespread famine in developing countries in the coming decades.

Is there enough regulation of GM food?

YES: Industry scientists start by comparing a GM plant with conventionally bred plants of the same variety. Their goal is to see whether an introduced gene alters the GM plant's chemical make-up and nutritional value. If the protein made from the new gene is the only discernible difference between the two plants, scientists test that protein for toxicity by feeding it to animals in amounts thousands of times higher than a person would ever eat. Scientists also test for allergy-inducing potential by checking the chemistry of each new protein against those of about 500 known allergens.

Industry spokespersons argue that this testing system has worked well. When scientists realised that a gene from Brazil nuts they were planning to splice into soybeans might sicken people who have allergies to nuts, they discontinued the experiment. Similarly, when other researchers discovered that a protein in one type of GM corn might cause allergies, regulators approved that corn only for animal feed.

Biotech firms point out that not one but three U.S. government agencies have their say about each GM crop. Under pressure from activists, these agencies have stepped up their vigilance.

NO: GM crops have been developed and grown too quickly and too broadly, without adequate testing or public debate, especially in the USA where 75% of GM crops are grown. It is felt that the government bodies that regulate GM crops in the USA are too lax. Biotech companies are not required to consult with these bodies on new GM foods, and even those that voluntarily do so do not have to follow their recommendations. In the USA, GM foods do not have to be labelled as such so people do not know what they are eating. If they get sick from eating GM food, no one will be able to trace the illness back to its source.

For sustainable food growers, genetic modification flies in the face of all the ideals concerning nature and the use of natural rhythms to sustain the elements on which our food growing is based. GM seeds are usually patented, so that farmers face legal action if they collect the seeds themselves. In any case many plants have the so called 'terminator' gene, which makes all the seeds sterile. Most sustainable food growers find it hard to see how GM plants fit into their way of food growing. Their very existence does not stem from nature but from a laboratory, and they are developed in a way that produces dependency on the companies that produce them rather than nature.

GROWING OUR OWN SEED

In Buddha Garden we grow all our own seed for the plants that will produce seed in this climate. We still have difficulties with producing lettuce seed (it does not germinate very well) and have never managed to produce rucola (rocket/arugala) seed in the quantities that we need. We therefore have to depend on getting these seeds from a different climate zone where they grow more easily.

One of the big bonuses for us in saving our own seeds is the way this has affected the pest problems that we experienced when Buddha Garden started. When I first started growing pumpkins they would soon be covered in little red bugs that would sometimes eat the entire plants. This meant that the plants either did not produce any pumpkins or were only able to produce very inferior ones. As we started to save our own pumpkin seed, we noticed that over time successive generations of plants seemed to be able to repel these bugs. Now when we grow pumpkins we still see some red bugs on the plants, but they do very little damage. This is not the only reason this has happened (for more information see the section on Insects), but growing our own seed has enabled our plants to adapt to the particular conditions in Buddha Garden, which includes insect pests and how to resist them.

As mentioned before, having our own open pollinated seeds means that each crop of vegetables that we grow has a wide variety of characteristics. As the climate changes, with higher temperatures and more erratic weather systems, it is more likely that some of the plants will survive and adapt to these changing times. This makes our plants, and us, more resilient. We obviously save quite a bit of money by growing and saving our own seed, and we have found it very reassuring in the event of cyclones and other extreme weather events to have our own seed immediately available.

Growing, collecting and using our own seeds is the heart of what we do to create a sustainable Buddha Garden.

WHAT SHALL WE DO WITH THE WEEDS?

Weeds are simply plants growing in places where they are not wanted. It should be remembered, however, that many weeds are extremely resilient and are often able to extract nutrients from poor soil much more effectively than other plants. They have different root systems, which can absorb nutrients from the soil that crop plants are unable to do. Their tissues can, therefore, be a storehouse of nutrients for other plants. For this reason, weeds should always be recycled back to the soil, either after passing through animals or compost heaps that break down the nutrients into a source that other plants can absorb.

Like all plants, weeds need access to water, nutrients and light to grow. The farmer's goal is to ensure that the crop is grown in a way that outnumbers and therefore marginalizes the weeds, thus reducing the availability of resources to the weeds and resulting in their limited growth. The crop, therefore, needs to be given a competitive edge in the following ways.

CULTURAL PRACTICES TO CONTROL WEEDS

CULTIVATION is probably the most widely used form of weed control in organic vegetable operations. Mechanical cultivation uproots or buries weeds. Burial works best on small weeds, while larger weeds are better controlled by destruction of the root-shoot connection or by slicing, cutting or turning the soil to eliminate the root system's contact with the soil. Cultivation requires relatively dry soil with subsequent irrigations being delayed long enough to prevent the weeds from re-rooting. From the very beginning, I found that trying to use weeds as mulch on our irrigated beds was not possible. The weeds never seemed to dry out sufficiently enough so as not be resuscitated with even a little water from the irrigation system. In the end I had to accept that Indian weeds are very persistent and strong, and now I take them straight to the compost heap for recycling.

In Buddha Garden cultivation is our main form of weed control. We try to weed at a time in the life cycle of the seedling to give them a head start on the weeds. The seedlings grow and produce a shade canopy, which impedes the growth of weeds enough so that they do not affect crop production. We have found this to be particularly useful on our maize beds.

SOIL STERILIZATION involves the use of heat or naturally generated biocides to kill weeds. Heat can be applied with steam, which is injected into the soil to kill the weeds' seeds. This method can only be used during times when the beds are not being used for growing crops. The large quantities of fuel, water and machinery needed for this technique make it an expensive choice, with questions being raised as to its sustainability. Soil can also be sterilized by the process of solarisation. This involves placing a piece of plastic over the soil, which then sufficiently heats up in the sun to destroy the weed seeds. Since this process can take up to four weeks, and much longer in less hot climates, it is not suitable for intensive horticulture. There is also the question of cost and how the waste plastic is to be dealt with. Sometimes during the very hot season we turn off some of the irrigation on our beds, and find that even just allowing the bed to dry out and get hot does reduce the weeds a little when we start planting crops again.

MULCH covering the soil, with mulch if thick enough, blocks the light and prevents weed germination and growth. The materials that can be used as mulches are varied, and include plastics and organic materials such as municipal yard waste, wood chips, straw, hay, sawdust and newspaper. To be effective, mulch needs to block all light to the weeds, and some mulch materials require a thicker application layer than others to accomplish this.

Plastic mulches vary in thickness from 1.5 mm to about 4 mms. The most common colour for weed-control plastic is black, since it completely blocks light. They are extremely efficient at keeping the weeds at bay, but they are expensive, and in Buddha Garden we are concerned as to how we can dispose of the plastic after use. There are also difficulties in keeping the mulch in place under windy conditions, and they are only suitable for use with drip irrigation. It is now possible to buy so called 'organic weed mats', which work like plastic but can be certified organic and eventually break down into the soil. They have not yet reached the Indian market, so for us they are too expensive and difficult to obtain.

Organic mulches such as municipal yard waste, straw, hay and wood chips must be maintained in a layer 4 or more inches thick in order to block out light. Organic mulches break down over time, and the original thickness typically reduces by 60% after one year. We used to use straw for mulch, which would provide a beautiful thick cover for quite a long period of time. As straw is cattle food here in India, it was extremely expensive, and we had a lot of trouble finding organically grown straw, and frequently were unable to do so. We now use leaves collected from other Auroville communities. This has the advantage that it is cheaper, although we do have to pay to get them picked up. They also break down and blow away more easily than straw, but we find they work quite well and provide a lot of organic matter to the soil.

Living mulches include velvet beans, clover and sun hemp. They must be used with care to make sure that they do not compete aggressively with the crop. In Buddha Garden we have tried using some of these without too much success. This was usually because the green manure took nutrients away from the crop. We have had much more success with growing the nitrogen-fixing plants separately, and then cutting them to put on the bed as mulch for the crops grown next.

Birds such as geese and certain species of chickens can be used for weed control. They are probably more useful in orchards and with bushes and trees rather than vegetable gardens, where great care has to be taken to ensure that they eat only the weeds and leave the crops alone. We have found that when our chickens have strayed into our vegetable gardens they have eaten everything in sight.

From the very beginning, we in Buddha Garden have accepted weeding to be an unending job. Personally, I rather enjoy it as it gives me a chance to look at all the plants closely as I weed them as well as to check up on things like soil moisture and fertility.

As weeding takes up a considerable amount of time and energy, and as the farm has grown in size and productivity, we are always looking at ways in which the weeding can be reduced. On the raised beds we were aware that many of the weeds were rooted on the paths and creeping up the sides of the bed. If we could stop the weeds on the path we could stop a lot of weeds on the beds. Eventually we managed to get funding for building brick sides to the beds. This has worked as a barrier between the path and the beds, thus completely cutting down on a major source of weeds in the garden.

I have mixed feelings about weeds. At times when we do not have enough people to keep up with the weeding it can feel as if the farm is gradually being returned to the jungle. And even although at times I would like to do less weeding, if there were no weeds at all how would we make our compost?

(I have come across few books in praise of weeds, but one of them is *Weeds: Guardians of the Soil* by Joseph Cocannouer. He describes the way he began to understand what the role of the weeds in the soil might be. As they did not necessarily impede crop growth, but could play an important part of in enhancing soil fertility.)

BASIC PRINCIPLES FOR LOOKING AFTER YOUR PLANTS

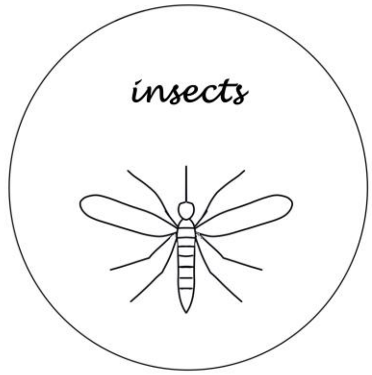
Grow a range of food producing plants that do not all take huge amounts of energy to care for. Vegetables generally need a lot of time and energy to look after. Fruit trees and other perennial plants (plants that don't need replanting each year) take less time and energy. Grow what you have the time and energy to care for and like to eat.

Grow local plants in season as these will usually require the least amount of water and will be adapted to the local climate as well as being resistant to local pests. Save your own seed so your plants adapt to your garden and can deal with the pests and other conditions there.

Grow young seedlings in a protected area such as a nursery. The protection they require will depend on the climate and local insects. Some seedlings are more delicate than others. You will need to understand how the plants you grow breed and the special things they need to grow well.

Plant your seedlings in the best place for them to grow. All plants need a fertile soil with enough moisture, space and the right temperature. There might be some places in your garden where some plants grow particularly well.

Watch how your plants grow; build up a relationship with them and see how they respond to different types of care you give them. Over time this will enable you to understand the best way of taking care of all the different plants that you grow.



During the first year in Buddha Garden, one of the worst problems I had to face was dealing with insect pests – or ‘poochies’ as they are colourfully called in the local tongue. This wonderful Tamil word embraces all creepy-crawly things that eat crops when you do not want them to. At the time I wrote in my diary:

I still seem to be in continual battle with the bugs. Everything is affected in some way and no end is in sight. All very young plants are susceptible, but so many of the vegetables that we manage to grow are also full of poochies of one sort or another. We were so proud of our first snake gourds, but they were very small and when we opened them inside they were crawling with pests. There were quite a few cucumbers, but again when we looked at them closely they were also full of bugs. Same with the pumpkins, only two or three of these and one at least was full of poochies and another had gone bad. Ladies fingers are also difficult as they are host to borers, which come right inside the vegetable and are not always visible from the outside.

We were appalled at how quickly our hard work could be decimated with a few determined insects.

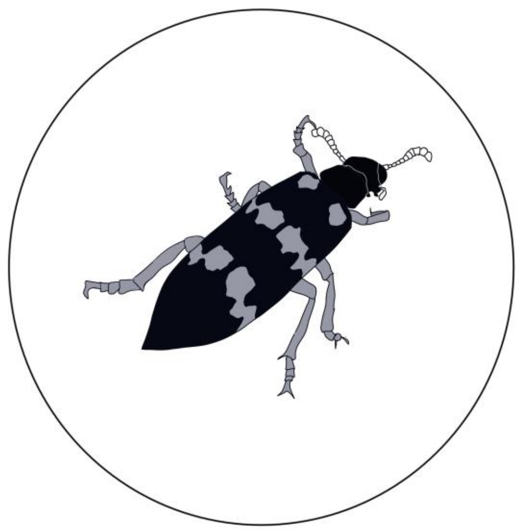
One morning while Arjunan (an Aurovilian who worked with me at that time) was doing the early morning spraying, he noticed that a bed of spinach was infested by caterpillars munching away as fast as their little jaws would go. They seemed to have appeared out of nowhere. I could hardly believe that only an hour or two before we had been standing and admiring the beautiful green plants. The bed was crawling with them, and I was SO upset as by the time we managed to pick them all off, the spinach had more or less disappeared. I have left it to see if it will re-grow as it’s that sort of spinach, although so far there doesn’t seem to be any sign of it doing so. (It never did recover.)

As food growers we often tend to talk about insects only in terms of insect pests and how to get rid of them. Despite my initial experience of feeling overwhelmed by insect pests when I came to Buddha Garden, it is good to remember that only 1% of the total known insects in the world are pests. In the beginning we had rather the same attitude as a chemical farmer and tried to eradicate the pests with sprays each time they appeared. We tried a number of local pest control remedies, including sprinkling the affected plants with ash and spraying with water in which neem seeds had been soaked. Once I remember we spent three days making a most complicated concoction, which included chilies and ginger. These all had to be ground up, very messily, with a large granite grinding stone and then soaked for several days, after which the water was filtered through cloth and then sprayed on the plants. In every case, however, it seemed to have little effect. Insects would jump off the plants as we sprayed, but in most cases I could see them quickly jumping back on again as we walked past.

It took me a while to realise that this confrontational approach was not going to work, and that instead of trying to eradicate pests another way was needed. We had to find a way of living with them while at the same time not allowing them to spoil our crops. This has taken some time, as it means understanding the whole insect life in the garden, not just the ones that are causing problems, and finding ways to work with them. The reality is that most insects are essential for healthy plant life in the garden, and that more rather than less insect species in a garden increases the diversity which keeps the number of insect pests in balance.

WHAT ARE INSECTS?

Scientifically speaking, insects are a group of arthropods which are invertebrates with jointed legs. They make up about 75% of all the animals on earth, and have a major role in maintaining eco-systems as pollinators, recyclers of nutrients, scavengers, and food for other animals. Insects evolved soon after plants, and there are more insects and more species of insects than any other living organisms on earth. Estimates about the number of insect species range between 2 and 30 million, and globally scientists have identified around 900,000 species. So, there are still a lot of insects to discover. They are the most diverse group of organisms on earth, but have the following five basic physical characteristics.



- An exoskeleton, which means having a hard shell-like covering on the outside of the body;
- A body divided into a head, thorax and abdomen;
- Antennae on top of their head;
- They all have six legs;
- Most have wings and can fly.

Insects can be found in all places. They are adapted to every land and freshwater habitat where food is available, from deserts to jungles, from glacial fields and cold mountain streams to stagnant, lowland ponds and hot springs. Many live in quite extreme environments where other animals and plants struggle to live. Their success in colonizing all these different places is thought to stem from their basic characteristics. Being small and able to fly means they can both escape from enemies and go to new environments, while their hard, protective exterior helps them deal with a range of environmental hazards. Insects remain small because having an exoskeleton means that they cannot grow past a certain size. Otherwise they would be too heavy to move around.

INSECT LIFE CYCLES

With a hard, outer shell that does not grow, insects develop from birth to adult by going through a three-or-four-stage growth process. The three-stage process is known as incomplete metamorphosis (or hemimetabolous development) and the four-stage process as complete metamorphosis. In both cases at the end of each stage the growing insect moults. It sheds the old exoskeleton and then forms a new one.

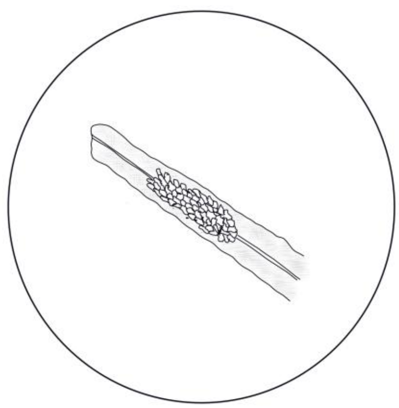
INCOMPLETE METAMORPHOSIS

An example of an insect that goes through this three-stage process is the dragonfly, but cockroaches, termites and many other species also follow a similar process.

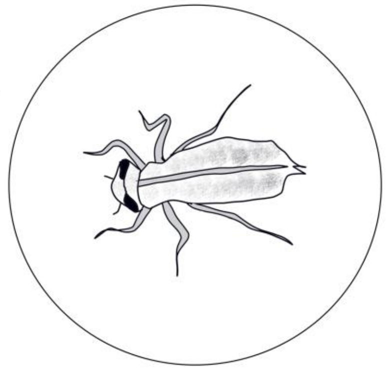
Dragonflies have been on the earth for 300 million years, making them one of the oldest species of insects in the world. Dragonflies were some of the first winged insects to evolve. The only difference between modern and ancient dragonflies is size. Modern dragonflies have wingspans of only two to five inches, but fossil dragonflies have been found with wingspans of up to two feet.

To begin the cycle the female dragonfly, after mating, lays eggs in a pond or marsh on submerged aquatic plants or mud. The eggs are only laid in still water, as eggs laid in quickly moving water will wash into fish-feeding areas. Depending on the species, a female can lay hundreds or thousands of eggs during her lifespan.

For dragonflies living in temperate regions, mating and egg laying typically occurs in mid-to-late summer. In temperate regions (areas where winter temperatures drop near or below freezing), dragonfly eggs usually will not hatch until the following spring. In tropical regions, dragonfly eggs may hatch in as little as five days at any time of the year.



When dragonflies hatch they are called nymphs. These have no resemblance to their adult forms and during this period of their development they are voracious predators. They molt (shed their skin) up to 12 times, depending on the species, and can spend as long as four years as nymphs.



Dragonfly nymphs are aquatic, living in ponds and marshes until emerging to molt for one final time. During the final molting, the nymph's skin splits and the nymph emerges as an adult dragonfly.

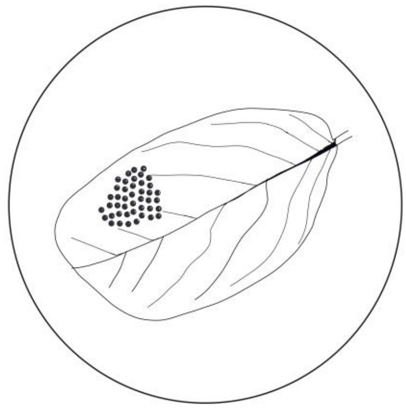
After the final molt from nymph to adult, occurring in late spring or early summer in temperate regions and at any time of the year in tropical regions, most dragonfly species spend the next month fully maturing. Their gonads (sex organs) finish developing, their colour becomes brighter with their final markings emerging and they disperse, sometimes hundreds of miles, from the pond or marsh where they developed.

Adult dragonflies are voracious predators eating small insects, primarily mosquitoes and flies, which they catch while flying. Dragonflies can hover, fly backwards, forwards and sideways. Dragonflies, which eat insects as adults, are a great control on the mosquito population. A single dragonfly can eat 30 to hundreds of mosquitoes per day. Dragonflies in tropical regions do not live as long as dragonflies in temperate regions. The reason? Dragonflies in temperate regions usually spend several years as eggs or nymphs before finally emerging as adults. This is how they deal with low temperatures during the winter. Dragonflies in tropical regions can go through the whole process in a year or less.

COMPLETE METAMORPHOSIS

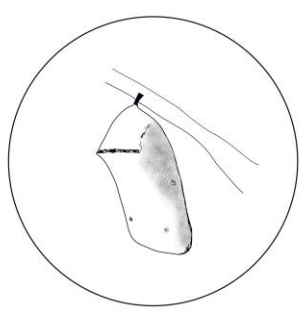
The four-stage growth process is known as 'complete metamorphosis' and comprises egg, larva (caterpillar), pupa (chrysalis) and adult. Examples of insects that have this growth cycle are butterflies, moths, beetles, flies and bees. Each stage has a different goal – for instance caterpillars need to eat a lot and adults need to reproduce. The larva is usually very different from the adult and generally eats completely different types of food. Depending on the type of butterfly and the climate in which it lives the butterfly life cycle can take from one month to a year or more to complete.

As with dragonflies the process starts when the female butterfly lays eggs.

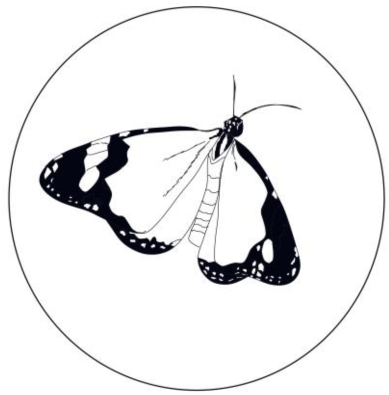


Usually this is done on plants that provide food for the caterpillars that will emerge from the eggs. The egg shape depends on the type of butterfly that laid the egg. When the egg hatches, the caterpillar emerges. Since most caterpillars are tiny and cannot easily travel to a new plant, the caterpillar needs to hatch on the kind of leaf it needs to eat. Caterpillars start off extremely small and need to eat a lot so they can grow quickly. Once eating, they instantly start growing and expanding. Since their exoskeleton (skin) does not stretch or grow, they grow by "molting" (shedding the outgrown skin) several times until they reach the final stage of life as a caterpillar.

As soon as the caterpillar has finished growing and reached their full length/weight, they form themselves into a pupa, also known as a chrysalis. From the outside of the pupa, it looks as if the caterpillar may just be resting, but on the inside a lot is going on. Within the chrysalis the old body parts of the caterpillar are undergoing a remarkable transformation, called 'metamorphosis', to become the parts of the butterfly that will emerge. Tissue, limbs and organs of a caterpillar have all been changed by the time the pupa is finished, and is now ready for the final stage of a butterfly's life cycle.



When the caterpillar has done all of its forming and changing inside the pupa, the adult butterfly emerges. When the butterfly first emerges from the chrysalis, the wings are soft and folded against its body. Usually within an hour to three hour period, the butterfly will expand its wings and will search for a mate in order to reproduce. When in the fourth and final stage of their lives, adult butterflies are constantly on the look-out to reproduce, and when a female lays her eggs on some leaves the butterfly life cycle will start all over again. Adult butterflies are important pollinators for some flowers.



INSECTS AND THE ENVIRONMENT

Since insects make up the majority of land-living creatures on earth it is not surprising that they play a significant role in the ecology of the world, especially as they interact with all parts of that world – plants, other animals and each other. Many insects feed on other insects and in so doing keep the populations they feed on in check: caterpillar hunter beetles, pirate bugs and praying mantises keep populations of herbivorous insects at a reasonable level. Equally important are parasitic insects, a prime example being braconid wasps that lay their eggs on tomato hornworms. When the wasp larvae hatch, they feed on the hornworms.

Insects have very important functions in the environment with regard to nutrient recycling and pollination. It is insects that carry out the first process of making large pieces of organic matter smaller before they are further digested by smaller organisms such as fungi and bacteria. Pollination is another crucial role that insects have in our ecosystem. Both these processes are essential to the food-growing process, so food growers need to know what insects are involved and how they work in their particular situation.

NUTRIENT RECYCLING

Without insects the earth would be awash with various sorts of dead organic matter. We are dependent on insects, and towards the end of the breakdown process other living organisms, like bacteria, to break down this material. Then it can provide nutrients for plants, and often at the same time nutrition for the insects involved in the process. Although bacteria are the final decomposers, efficiency rises when larger organisms first prepare plant material for decomposition, to a large extent, by eating leaves and producing fecal pellets. In Buddha Garden every time we make a compost heap we rely on insects that break down organic material to turn the original heap into plant food.

There are several major groups of insects involved in this process.

Insects that feed on dead or dying plant tissues

This includes a wide variety of soil- and wood-dwelling species that shred leaves or tunnel in woody tissues. They accelerate decay by increasing the surface area exposed to weathering and the action of other decomposers like fungi and bacteria. Often, they are responsible for creating a layer of humus that can be seen covering the soil. This layer serves as an incubator for the fungi, bacteria and other micro-organisms that release carbon, nitrogen and mineral elements which are food for living plants. In Buddha Garden we have our fair share of termites, that we generally see as a dreadful nuisance, especially if they get into our houses and cause damage. Yet they can be very beneficial, as with the help of micro-organisms in their gut they can digest wood and cellulose in the soil, materials that would otherwise take a long time to decompose.

Those that feed on dead animals (carrion)

Carrion feeders include numerous beetles, fly larvae (maggots), wasps, ants, mites and others that are collectively known as saprophages. Each species colonizes the dead body for only a limited period of time, but as a group they rapidly consume and/or bury the decaying flesh. Blow flies, usually the first to arrive on a carcass, are also the first to complete development and depart. Other species follow over time in a relatively predictable sequence as the body decomposes. This change in the insect species is called faunal succession, and can provide a reliable way to determine the time elapsed since death. This is a useful tool for police, medical examiners and other practitioners who need to estimate times of death.

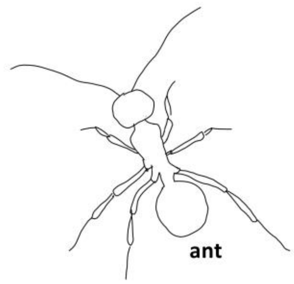
Those that feed on the excrement (feces) of other animals.

Many species of manure flies and dung beetles are attracted to the odour of animal excrement. Adults lay their eggs on fresh feces, and the larvae then feed on the organic matter in these waste products. Many dung-feeders exhibit distinct preferences for particular types of manure: the species associated with horse manure, for example, may be quite different from those found on the same farm in cattle manure.

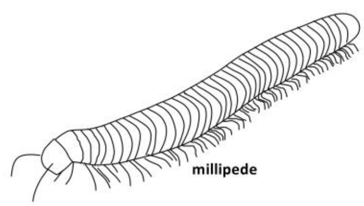
In addition to their role as decomposers, some saprophagic insects also serve as pollinators for plants like skunk cabbage and wild ginger. These plants produce drab-coloured, foul-smelling flowers that attract the attention of blow flies or carrion beetles. The insects crawl around in the flowers looking for food and unwittingly pick up pollen. Finding nothing to eat, the insects leave and continue to forage for food, perhaps visiting another blossom and transferring pollen.

Even after their death the bodies of insects are an important soil component, as their bodies are largely composed of nitrogen. These are some of the insects that we are very happy to see in our compost heap.

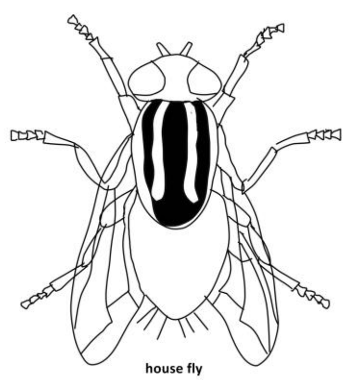
Ants feed on a variety of materials, including fungi, seeds, sweets and other insects. They help the composting process by bringing fungi and other organisms into their nests. Ants can make compost richer in phosphorus and potassium by moving minerals around as they work.



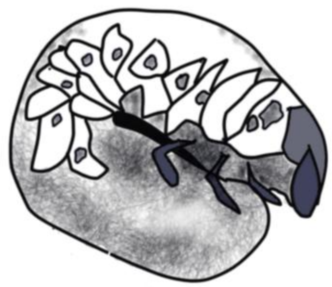
Millipedes have worm-like segmented bodies, with each segment having two pairs of walking legs (except the front few segments). Millipedes help break down plant material by eating soft decaying vegetation.



Flies are two-wing insects that feed on almost any kind of organic material. They also act as airborne carriers of bacteria, depositing it wherever they land. Although flies are not often a problem associated with compost piles, you can control their numbers by keeping a layer of dry leaves or grass clippings on top of the pile. Also, bury food scraps at least eight to twelve inches deep into the pile. Thermophilic temperatures kill fly larvae. Mites help to keep fly larvae reduced in numbers.

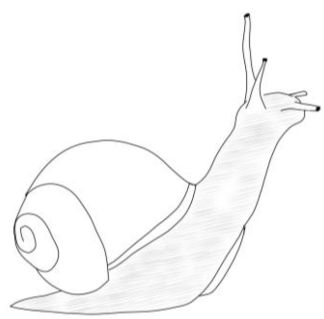


Beetles are insects with two pairs of wings. Depending on where you are there are many types found in compost piles. In Buddha Garden we often come across these grubs in our compost heaps, either in the leaves that we use for making compost or in the compost itself. They are the larvae of the rhinoceros beetle, which spends two to three years in this form. They help to break down large amounts of organic material so we are always happy to see them.

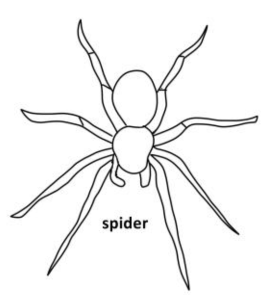


larvae rhinocerus beetle

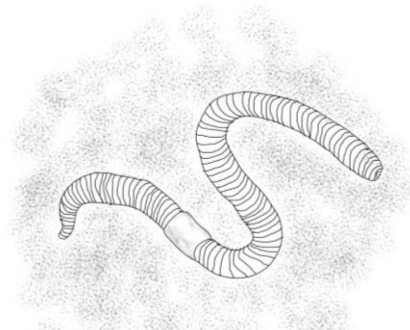
Snails and slugs are molluscs that travel in a creeping movement. Snails have a spiral shell with a distinct head and retractable foot. Slugs do not have a shell and are somewhat bullet shaped with antennae on their front section. They feed primarily on living plant material, and years ago we had a lot of problems with leather-backed slugs, which is not a local slug. These creatures will also feed on plant debris in the compost heap.



Spiders are eight-legged creatures that feed on insects and small invertebrates. They can be very helpful for controlling garden pests.



Earthworms are the most important of the large physical decomposers in a compost pile. Earthworms ingest organic matter and digest it with the help of tiny stones in their gizzards. Their intestinal juices are rich in hormones, enzymes and other fermenting substances that continue the breakdown process. The worms leave dark, fertile castings behind. A worm can produce its weight in castings each day. These castings are rich in plant nutrients such as nitrogen, calcium, magnesium and phosphorus that might otherwise be unavailable to plants. Earthworms thrive on compost and contribute greatly to its quality. The presence of earthworms in either compost or soil is evidence of good microbial activity.



When I first came to Buddha Garden, we hardly ever saw a worm, and finding one was a reason for celebration. Now they are in evidence everywhere, especially on our raised beds, which shows how much the soil has improved.

POLLINATION

As described in the section on plants, pollination – the mixing of male and female plant sex cells – is needed by all plants to produce fruit and seed. While some plants are self- or wind-pollinated, the great majority of flowering plants, more than 70% of species, cannot move pollen without help from an animal/insect pollinator. Plants depend on insects, birds, bats and other animals to transport the pollen for them. Insects usually visit the flowers to collect nectar that they eat, but at the same time carry the pollen from flower to flower. Many insects have specialized anatomies to do this, like the 'pollen baskets' on the legs of bees or specialized hairs on some species of beetle. Some plants such as orchids have co-evolved with the insects that pollinate them, so that the anatomy of the insect perfectly fits the size and shape of the flower, making pollination easier.

Worldwide, at least a third of the 1,500 crop plant species depend on pollination by bees and other insects. It has been estimated that one in every three mouthfuls of food we eat has been pollinated by a bee. Thus, pollinators are important in the production of an estimated 30% of the human diet, together with fibres, edible oils and medicines created from plants around the world. The south-eastern blueberry bee illustrates the economic significance of native pollinator. In her few weeks as an adult, a *single* female bee visits about 50,000 blueberry flowers, resulting in over 6,000 marketable blueberries worth about $75. Bumble bees have long been recognized as important pollinators of crops and native plants. In recent years, they have been reared commercially and used to pollinate greenhouse crops, particularly tomatoes and eggplant. Pollinators play an essential role in ensuring that we do not go hungry.

BEES

To humans, bees are clearly the most important pollinator. Without bees, many of the plants we rely on would not be able to reproduce. The foremost food product from these insects is honey, which is developed by honey bees from the nectar they collect from flowers – their "reward" for all that pollinating.

Honey bees, which were originally imported from Europe to aid us in pollinating our food crops, have suffered in the past decade from mites that invade their breathing tubes and external bodies. There has been much research and effort into solving this problem, including the import of a resistant strain of honey bees from Russia. Many factors are believed to be responsible for what is being called "Colony Collapse Disorder": some combination of pathogens, parasites, environmental stresses and management stresses are likely to be contributors to the cause. The impact of diseases, parasites and pathogens on pollinator populations is of growing concern. Managed honey bees are affected by parasitic mites, diseases such as foulbrood, and pathogens. Commercially reared bumble bees are also affected by diseases and pathogens, and there is evidence that these can spread from commercial colonies to wild colonies around greenhouses. Many experts suggest that these declines illustrate the danger of our heavy reliance on a single species for most of our pollination needs.

Further research is necessary to improve the understanding of pollination dynamics and the consequences of pollinators. Specifically, we need to know more about the effects on wild pollinators of pesticides, grazing, logging and urban sprawl, the significance of diminishing pollinator populations, and the potential for cascading extinction.

DEALING WITH PESTS

Many modern 'industrial' farmers deal or have tried to deal with insect pests by trying to get rid of them completely with pesticides. These poisonous chemicals either disable or kill them, which has many short- and long-term negative effects, both for the earth and ourselves:

Chemicals that kill pests will also often kill useful insects and other living things like bacteria. This was one of the problems of DDT, which killed everything and would kill all the good bacteria in soil and water making it dead and therefore unable to support life.

The pests that chemicals kill are part of a sometimes very complicated network of different life forms. When the pests are removed from such a network, this can have negative effects on the other animals and insects in the network. Perhaps the removal of the pest affects the amount of food available for the animals that fed on the pest. Or the insect that was food for the pest is now able to over breed and perhaps become a pest itself. Often it is difficult to tell what short- and long-term effects the removal of a pest will have on the intricate network of animals, insects, plants and microbes. Often, we may never know what the long-term consequences for the earth will be.

Pests become immune to the chemicals, sometimes very quickly. Then more and more of the chemical must be used and/or new and even more poisonous chemicals be created.

Eating food sprayed with some of these chemicals is bad for human health. This can be either directly or, more likely, because the chemical stays in the environment for a long time and gradually gets into the human food chain through poisoning soil and water.

Workers who use the chemicals can get sick and/or it affects their unborn babies.

Chemical pesticides can be very expensive and difficult for farmers to afford.

In the beginning in Buddha Garden we took a similar view to the industrial farmer and tried to get rid of any pests that showed up, although we used natural pesticides that we made ourselves rather than chemical ones. Usually with only limited success. Over the years we have realised the limitations of this approach, and that such an elimination, even when we can manage it, comes at a cost. We can eliminate a pest, but if this disturbs natural cycles that have positive benefits this can eventually lead to very bad consequences for the environment, which includes the whole of Buddha Garden. We have also realised there is no one substance or technique that will get rid of all the pests and diseases that might visit us.

Like other sustainable farmers we do not now try to get rid of pests, and instead we look for ways to prevent them from turning into a problem. This means knowing as much as possible about the life cycle of all the pests and diseases that might attack our plants, and any possible weaknesses of the plants, which might make them more open to being attacked. Only then can we deal with insect pests in a way that does not upset all the very positive benefits that insects bring to our food growing.

There are a range of possible techniques to keep the pests and diseases at a level where food can still be grown. Sometimes called 'integrated pest control' this might include:

Creating a healthy soil from which stronger, more pest-resistant plants can grow. In Buddha Garden we have found that this is the most important way of preventing pests from being a problem. Year after year we find that a healthy plant in a healthy soil is our best defense.

Creating a diverse system of plants and insects: the food grower cannot hope to emulate the diversity of nature, but creating as much diversity as possible in the bacteria of the soil, species of insects and the plants grown will help to create a balance that keeps pests under control. This was graphically demonstrated to us by a student who carried out a very elegant piece of research on some three pests in Buddha Garden. She found that the more species of insects she counted on a piece of ground, the fewer the number of every pest in that same area. In other words, the more diverse the insects the fewer the pests.

Dealing with pest and disease outbreaks quickly: Knowing where and when a pest is most likely to attack the plant is essential. The plant can be checked efficiently and any needed action can be taken as soon as possible. We remove diseased plants or crops as quickly and completely as possible. We usually find this prevents pests from infecting the rest of the bed if we removed the diseased plants quickly enough. Any weeds that play host to certain pests need to be removed as well.

Growing pest-resistant strains of plants: These are often traditional/non hybrid varieties. All the plants that we grow are local plants, which we grow in season when they are likely to grow at their strongest.

As mentioned in the section on plants, we have noticed that over the years, as we have been using our own seeds, our plants have learnt how to deal with the pests we are likely to see in Buddha Garden.

Using nets and other covers to ensure that flying pests cannot reach the crop.

Practising crop rotation ensures that pests do not build up in the soil, and that the food for certain pests is not always in the same place. The last time we had a pest problem in Buddha Garden we realised we had inadvertently planted two very similar successive crops. This had led to a build-up of pests which meant that the second lot of plants were mercilessly attacked by a species of beetle. Once we had realized our mistake we replanted the second crop, with something completely different, and the beetles went away on their own.

Trap cropping: A crop susceptible to the pest is planted as a trap, and then the crop is destroyed once the pest has reached a certain part of the life-cycle. This works well for some nematode pests in the soil that are difficult to eradicate by other means. We have found that growing marigolds in and around tomatoes helps to keep the soil nematodes in check.

Intercropping or sometimes known as 'companion planting': A crop is grown next to the main crop to attract the pests so that the main crop is left untouched, or the companion plant can repel the pest both from itself and the crop.

Adjusting planting times: Pest-outbreaks often occur in particular soil and climate conditions. When possible, planting times can be adjusted to avoid these times. Our planting schedule for the different seasons takes into account the fact that some plants get attacked in certain seasons. If we have a very wet monsoon, for instance, we stop growing beans as generally they get covered with mold and aphids during this time.

Biological sprays can be used to spray on the pest directly: It is best if such sprays are made with a plant that grows naturally on the land where the crops are also growing. Sprays can include:

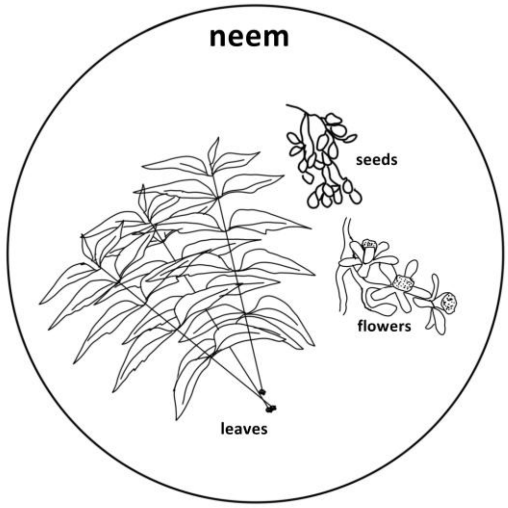
Bacteria which when sprayed on a plant either kill or disable the pest at a certain stage of its life-cycle. To control root problems, seedlings can be soaked in a solution of the bacteria.

Natural chemicals can be used to make sprays against pests. In India neem, pongamia and madhuca trees can be used. The food grower needs to know what the right plants are in the place where the food is being grown.

Biological sprays work best when they are used at the beginning of an infestation or as a preventative. To be successful, biological sprays need to be made using the correct parts of the plant in the right concentration. We used to use a lot of biological sprays, which were our main defense against insect pests. I can't remember the last time we used one – not because we did not want to but because we did not need to.

IN PRAISE OF NEEM

One of the most useful trees in Buddha Garden (and India as a whole), neem produces natural chemicals that are effective against a large number of insects and other pests. This tree is a native of tropical South East Asia, is fast growing, can survive drought and poor soil conditions, and keeps its leaves all year round. Although mentioned in 1,000-year-old Sanskrit medical texts, the tree's potential for effectively controlling insect pests has only recently become known.



The uses of various parts of the neem tree are as follows:

The wood is strong and resistant to termites; neem twigs make excellent toothbrushes with antiseptic properties so toothpaste is not required;

Neem extracts are used to prevent and treat many health problems: bathing with neem water can relieve heat rashes and boils; neem oil is used against stomach ulcers and rheumatism; neem bark contains a strong antiseptic that is used to make soap and other herbal preparations for the skin;

Neem leaves can be used to make things less acidic;

Neem extracts are used in the manufacture of mosquito repellants, fertilizers, diabetic and animal food;

Neem cake, which is what is left over when extracts have been taken from seeds and leaves, can improve the soil;

Different parts of the neem tree can be used in pest control as it has an effect on nearly 200 insect species as well as some nematodes, fungi, bacteria and viruses. Neem contains several active chemicals which work in different ways, this making it unlikely that the pests will become resistant to them. Generally, the chemicals are environmentally safe, as they are bio-degradable and not harmful to humans or animals.

The useful chemicals found in neem include a number of limonoids, which act in versatile ways on pests, such as:

disrupting or inhibiting the development of eggs, larvae and pupae;

blocking the molting of larvae and pupae;

repelling larvae and adult insects;

disrupting mating and sexual communication in insects;

deterring females from laying eggs;

sterilizing adult insects;

poisoning larvae and adult insects;

deterring feeding – blocking the ability to swallow.

While neem has a negative influence on a wide range of destructive pests, it does not affect beneficial creatures like earthworms or pollinators like butterflies and bees, lady bugs that consume aphids, and wasps that act as parasites on various crop pests. Neem is truly a renewable medicinal storehouse for physicians and farmers alike. Those of you living outside India must investigate which plants are suitable for using as natural pesticides. They will be out there somewhere, and may be even living close to where you are growing your food.

A WORLD WITHOUT INSECTS?

For the last fifty years we have changed the ecology of the world to such a degree that the insects on which we and the natural world depend are facing extinction. This is part of the general destruction of biodiversity and the ecosystem, which has reached levels that threaten our human well-being. We humans have already significantly altered three-quarters of all land and two-thirds of the oceans. More than a third of land and three-quarters of freshwater resources are devoted to crops or livestock. Around 700 vertebrates have gone extinct in the past few centuries. Forty per cent of amphibians and a third of coral species, sharks and marine mammals look set to follow.

A recent report from the University of Sydney, which reviewed 73 research papers on this subject, found that the biodiversity of insects is threatened worldwide. It seems that the numbers of species of insects is declining worldwide, and it is estimated that this could lead to the extinction of 40% of the world's known insect species in the next few decades. This could have grave consequences for the natural world and on our ability to grow food. The main drivers of species decline appear to be: habitat loss resulting from intensive agriculture and increasing urbanization; pollution from synthetic pesticides and fertilizers; pathogens and introduced species. Climate change is another factor that is already affecting tropical regions more than mountainous or temperate zones. The authors suggest that a fundamental rethinking of agricultural practices is needed. In particular, a serious reduction in pesticide usage and its substitution with more sustainable, ecologically-based practices. This, they think, would slow or reverse current trends, allow the recovery of declining insect populations, and safeguard the vital functions that insects provide for the ecosystem. In addition, there would need to be a large clean-up of polluted water systems both in agricultural and urban environments. If we want to avoid mass extinctions and preserve the ecosystems all plants and animals depend on, it has been suggested that large areas of oceans and land need to be regenerated and kept as sanctuaries for their biodiversity. We can begin by promoting and celebrating the insect diversity in and around where we live and grow food.

BASIC PRINCIPLES FOR LOOKING AFTER YOUR INSECTS

Insects are necessary to food growing: we need to know about the insects in our garden and respect their contribution to our food growing. We take measures to increase the diversity of insect species in our garden. The more insect species there are the fewer insect pests there will be.

We invite beneficial insects; by creating an environment where they want to live. This can be done by having undisturbed areas or creating places where the insects will come and live, such as putting out dead wood for carpenter bees or creating "bug houses" from small pieces of bamboo.

We deal with insect pests by realising that there is no one action that will eliminate them. We do not try to get rid of insect pests. Instead we look for ways to prevent them from turning into a problem. This means knowing as much as possible about the life cycle of all the pests that might attack our plants and understanding possible weaknesses of the plants, which might make them more open to being attacked by pests. We create an environment where pests are less likely to attack our plants.

When I set up Buddha Garden, I was very unsure about whether I wanted animals as part of the food producing process. I was concerned about the time and energy it took to look after them, and whether it was ethical to keep animals in this way. Traditionally, however, animals have long been important to humans by providing nutritious foods and as elements of environmentally-benign farming systems, as well as in some places being essential to human survival. Animals have evolved together with humans in a mutual interdependence, so that they have become part of our culture. Throughout human history livestock has been considered a form of wealth, traded and used as gifts, and offered as animal sacrifices. In India where I live cows are extremely important, and some local farmers have questioned how I can be farming 'properly' as we don't have cows. Not only do cows produce much wanted and highly priced milk, but they are also a source of very valuable dung on the farm.

In the history of animal husbandry, livestock has offered vital advantages to farmers. Some sorts of livestock such as goats and sheep can be raised in areas inhospitable to crops, and animals can graze on pastures unfit for growing food for human consumption. A combination of animal husbandry and agriculture has been shown to greatly increase the productivity of the land. Livestock can be used to supplement unreliable or uneconomical cereal crops, as it is less dependent on good weather and is less labour intensive. It can be carried out alongside most forms of agriculture. Where the soil is very poor (as it was in Buddha Garden), the dung from animals is extremely important for bringing the soil back to life.

Traditionally, farming livestock has provided the following benefits to humans:

Meat: In many agricultural societies, livestock replaced wild game as the primary source of animal protein. Domesticated livestock frequently eats forage and other food sources that humans are unable to eat but can easily supply.

Dairy: Mammalian livestock can be used as a source of milk, which can be turned into many value-added products like cheese, yoghurt, butter, etc. In countries with a well-developed dairy industry, 20–30 different milk products can be produced. Using the animal in this way creates much more food energy than can be obtained from eating the animal itself.

Honey and wax from bees: Honey is an important sweetener and often considered a medicine. Wax has many practical uses such as in making candles and furniture polish.

Raw materials: Animal wool and leather can be made into clothes, footwear, and other useful items. Bones, hooves and horns have a variety of industrial, cultural and decorative uses. Offal and non-edible parts can be used as animal feed.

Fertiliser: The manure from animals is an important source of fertiliser for plant crops, and is one of the reasons why, historically, agriculture and animal domestication have been intimately linked.

Labour: Before the advent of mechanical power, animal power was the only available source of non-human labour. The creation of the plough was a milestone in the history of farming, and having animals plough the land greatly increased the scope of agriculture and a farmer's productivity in general. Animals were also used to transport goods over long distances, and also had a function in the military.

Land management: The grazing of livestock is sometimes used as a way to control weeds and unnecessary undergrowth on a piece of land. For example, goats and sheep are used to eat dry scrub in areas prone to wild fires, in order to remove combustible material and reduce fire risk.

Given that there are over a hundred large land-based mammals, it is surprising that so few types have been domesticated. The reason for this relative paucity is that a lot of mammals do not meet the basic prerequisites necessary for domestication, such as having a readily available food source that can be controlled or supplied by humans, a rapid rate of reproduction, a moderate temperament, and a social structure that meshes well with human intervention. Climate, consumer demand, land type, animals native to the area and tradition all influence the predominant type of livestock in any given place.

Livestock may be kept in confinement in very small areas (cages or pens) as with poultry, rabbits, or veal cattle, or in sheds or barns, in fenced pastures, or on large open ranges where they are only occasionally collected in "round-ups" or "musters". Livestock may also follow a seasonal migration pattern where they are kept in confinement for part of the year and on pastures or ranges for the rest of the time, depending on the climate and the quality of food available. Since the advent of barbed wire (in the 1870s) and electric fencing technology, fencing pastures have become much more feasible and pasture management simplified.

One of the most controversial developments in agriculture has been the so called 'factory farming' of animals. Factory farming of a sort was practiced in Greek and Roman times, when farmers kept chickens caged or broke their legs and wings so they would not exercise, and therefore fatten quickly. Modern factory farming was first practiced in 1771 by an English farmer named Moody, who kept his cattle tightly confined in a dark, stuffy room. The profuse heat from their breath and warm bodies caused them to fatten faster and yield better meat.

Various sorts of intensive animal production have been widely adopted during the twentieth century. Pigs are kept in so-called sweat boxes, calves are bled to produce whiter veal, and chickens are mass-produced in closed buildings, never being allowed contact with the ground or nature. Growth hormones in fodder make the animals mature at quicker rates. Mass animal production in such close quarters creates a potential for the rapid spread of animal diseases that could devastate a farmer's operation. To combat this, antibiotics were developed during the 1950s to kill disease-carrying bacteria, through injection or by mixing it with the animals' feed.

Practitioners view these processes as a useful means of producing more food at less cost, but the quality of food being produced with the use of chemicals and antibiotics is questionable. Much concern has been voiced over the possible effects of hormone- and antibiotic-laden fodder on the human consumers of animal products. Animal rights activists protest about its utter disregard for the animals' comfort and welfare, as well as environmental concerns related to enforced breeding and the keeping of large numbers of animals in small spaces. Finally, of course, there is the issue of maltreatment as animals have to undergo painful procedures or live in ways that make them more like machines than living beings.

I think it was these kinds of issues that made me think about whether it was ethical or not to have animals in Buddha Garden.

During the first years we struggled with very poor soil, and it was clear that animal dung was necessary to bring it back to life. Yet I was sure that I did not want to look after cows, which are the usual domestic animal kept on many of the local farms. They were very time consuming to look after – needing milking twice a day, every day – and I didn't have the knowledge and experience to look after them successfully. At the time we were able to obtain the cow dung we needed from Siddhartha Farm situated adjacent to us, so it was not absolutely necessary for Buddha Garden to have animals as well.

During Buddha Garden's second year of operation, we were offered 30 chickens when someone who needed to get rid of them offered them to us. I had been wondering whether to have chickens or not, as I had enjoyed keeping them before while living in another community, and there seemed to be a good market for eggs. Initially I had the idea that they could eat things like weeds from the garden, so would not cost a lot to keep, and that their dung would be extremely useful fertilizer which was sorely needed. The eggs would provide a useful extra to the vegetables that we were selling. I envisioned a kind of 'backyard flock' where we would breed chickens ourselves. Since the chickens had been offered to us, we thought we would give it a try.

Our first challenge was to make sure that the chickens were secure. We had built a chicken yard, but found the chickens could fly out of it too easily and on several occasions caused a lot of destruction in the vegetable garden. A net over the top of their yard put a stop to further excursions. The chickens were a local variety which had been bred for the Indian environment. They could be best described as 'enhanced village chickens', which had the rugged qualities of the village chicken. These included adaptability to the extremes of heat and wet in the climate, resistance to disease, and being able to survive on the local diet. At the same time, they did not have the village chicken's propensity to sit once they had laid 15 or so eggs, and were much larger birds which could be sold for meat once their egg- laying days were over. Although they laid more eggs than village chickens, they did not lay as well as some non Indian varieties like white leghorns. I liked them because most of them seemed very friendly, easy going, curious and pleasant to have around.

From the very beginning we decided that we would try to feed the chickens as much as we could from the land of Buddha Garden. All the weeds and other material from the vegetable gardens was fed to them, which made the yolks of the eggs very yellow and the taste excellent. For the chickens to lay well, however, we found that we had to supplement their food with grain, which at the time we could not grow ourselves. We wanted to produce eggs that were 'organic', and so tried to find food that had not been grown with fertilisers and sprayed with pesticides. Unless we were able to buy the grain direct from a farm, it was very difficult to find out whether fertilizers and pesticides had been used. For commercial brands of 'chicken food' this information was not available at all. We eventually managed to find some local varieties of grain, which were probably grown without pesticides, although this was difficult to verify.

Because our chickens would not sit on eggs long enough for them to hatch, we got some village hens and used them as mothers to hatch more chicks. Generally, we found that if we put 10 eggs under a broody chicken, maybe 6–8 on average hatched with approximately half of them being male. A significant minority were also deformed in some way, and it was then that we realised that if we were going to keep chickens, even for eggs, we would be confronted with the task of killing some of them. In the beginning we used to let these deformed chicks live 'just in case they got over it', but they never did, and we should have killed them as soon as we realised that they were deformed. We also found that of the 6-8 chicks that hatched, usually one (through disease or other reasons) died before reaching adulthood.

Eventually we ended up with a flock consisting of half males and half females, which was obviously not sustainable unless we killed most of the males. We could not afford to keep chickens that were not producing anything. We decided to do this ourselves, as we felt that if we were going to keep chickens then we had to face the fact that some of them would have to be killed, and that it would be better if we did it ourselves. At least then we would do it as respectfully and with as little trauma to the animal as possible. I was not at all sure whether I would be able to do this, and if I had found it impossible to do then I would have stopped keeping chickens immediately. What I found was that provided we were killing chickens only occasionally, it felt reasonable. I was told that our chicken meat was very tasty, and I presume this was because our chickens had lived a more or less normal life eating a lot of 'wild food'.

We found it was a huge advantage for us to have the chicken dung for the vegetable garden, as it is high in nitrogen and the positive effects on the plants were very obvious. We also liked supplying those much appreciated eggs. For some time, I had had the idea of integrating chickens more closely with the vegetable growing, and when a volunteer, who was also a permaculture expert, came to stay in Buddha Garden, he encouraged me to set up our first integrated chicken unit. Interestingly, he came from Africa, where he told me that it was thought that domestic animals have chosen to live with humans as part of a reciprocal arrangement. The animal must therefore be cared for properly by us, and we should give thanks to the animal when it is killed to provide us with food.

The aim of the integrated chicken project was to integrate the chicken keeping with the vegetable growing. It consisted of:

A strong brick chicken house with an attached straw yard, all of which needed gates, locks and an overhead net to keep the chickens in and the predators out. As the name suggests, the yard was covered with straw, and all the material – weeds, etc – that came off the vegetable beds was put into the yard. Here the chickens ate as much as they could from it, and with their scratching and droppings gradually helped to break down this material. Every three months or so we took this material from the yard and used it for making compost.

Attached to the straw yard were three rotation yards, each equipped with their individual sprinkler irrigation systems. For a period of a few months the chickens were let into one of these yards, which provided them with more food and which with their scratching they cleared as well as composted. Then they went on to the next yard where they did the same thing while we planted vegetables in the cleared space. When the vegetables were finished, the chickens were allowed back into the yard to clear it in readiness for the next planting.

Once again, we investigated the possibility of growing the extra grains that the chickens needed on the Buddha Garden land, but this seemed impossible. We did have a piece of land where this could have happened, but we did not have the money for the necessary irrigation and other infrastructure. This was necessary, otherwise we would have been at too much risk of losing crops if the rains failed. This time we found a source of chicken food that did not have supplements like antibiotics in it, but were not able to verify that all the ingredients were grown organically – probably most of them were, but there was almost certainly a minority of chemically-grown ingredients.

Despite these problems, however, we continued to produce eggs which were much appreciated and for which there was an increasing demand. The food we managed to provide from the land gave the yolks a wonderful colour, and the eggs were very tasty. We were also very pleased with the way the soil in the rotation yards was becoming more fertile, and how we were able to use the material from the straw yard in our compost heaps. The extra food that we bought for the chickens was covered by what we received for their eggs, so it looked as if this was also an economically viable project.

Given the fast-growing demand for our eggs, we decided that we would build another integrated chicken house with rotation yards and try to do it on a larger scale. This was built more cheaply than the original one, but was still quite expensive given that every rotation yard had to be properly fenced and equipped with an individual irrigation system.

We planned to have 200 chickens in this new house, as with the rotation yards there was plenty of room for them and we knew that we would be able to sell the eggs. We explored whether to buy chickens 'at point-of-lay' – about six months old and ready to lay in a few weeks – or day-old chicks. Previously, I had bought chickens somewhat haphazardly from local breeders, with the chickens being anything from 6–12 weeks old. Also, in the past I had bought one group of 'point-of-lay' chickens from a reputable breeder, but it was clear that the chickens had been brought up in very close quarters, and they responded badly to the stress of moving and did not do well in our more open situation. They also seemed to be unnaturally large, which I found quite disturbing. I thought that maybe they had been fed antibiotics, or even hormones to make them grow, and that in Buddha Garden they found it difficult to do without them. Eventually most of them sickened and died – which was also the experience of another farmer who had got them from the same batch.

For the new project we therefore decided to buy only day-old chicks and to bring them up ourselves. We thought they would in the end be healthier and better adapted to our situation. We decided to get the same variety of chicken as previously, because we felt that although they didn't lay quite as well as some other breeds, they seemed to be healthier and provided more meat.

We were unable to get sexed chicks, so half of them turned out to be male, which we eventually sold as meat. This was when we found that having to kill this number was difficult – it is one thing to kill the odd few chickens now and again, but doing it day-after-day we found to be quite unpleasant. This showed us that we would definitely not want to grow chickens just for their meat. Eventually we ended up with around 100 chickens, most of which were female.

For this number of chickens there was no question of feeding them only from what came from the garden. Even if we had been able to grow food on the available land, it is unlikely we could have grown sufficient for all of them. Having this number of chickens made us realise just how much land it takes to feed such a flock. From the beginning we fed the chickens on chicken food which, although not 100% organic, did not contain antibiotics or growth hormones.

It took around eight months for the chickens to grow and start laying. As was usual, laying started slowly with small eggs but gradually the numbers and size of eggs increased. We had estimated that to cover food costs we would need at least 40 eggs per day, and since this meant that less than half the chickens had to lay each day this seemed like a reasonable forecast. In fact, we hoped that we would eventually get 60–70 eggs or more each day, which would help pay for the food during the time in which they were growing and not laying.

Unfortunately, even after four months of laying, the highest average of eggs per day was only 30. Then one day they stopped laying completely; this happening from one day to the next on July 25th for no apparent reason. We had gone through the really hot period when often chickens do not lay, and we could not think of any reason why they should suddenly stop. We continued feeding them well in the hopes they would start again, but they never did. In the following 30 days approximately 100 chickens laid only 30 eggs.

By this time, we had incurred considerable expenditure on food that looked as if it was never going to stop, so we decided to cut our losses and get rid of the chickens as soon as possible. The final loss was Rs 16,500, which was a large amount of money for us to make up through the sales of our vegetables.

Over the next few months we debated the pros and cons of continuing the chicken project:

Despite the way we kept the chickens we were still unable to produce completely organic eggs, as we could not grow sufficient food on the farm and did not have sufficient resources to grow our own. Food costs were high, so we ended up producing quite expensive eggs that were not organic. We could not justifiably increase the cost of our eggs, although they were obviously special in terms of taste and the colour of the yolks. We could possibly grow more food for the chickens in the rotation yards, but it was debateable as to whether we could grow enough, and we would then have fewer vegetables to sell.

One possibility would be to keep only the number of chickens for which we could grow food on the farm. Thinking in detail about this made it clear just how much land would be needed to feed one chicken, and so we could probably only keep quite a small number. The financial viability of doing this was questionable, unless we could charge a lot more for the eggs – which was not impossible. Many of our customers had said they would be willing to pay a lot more for organic eggs. They would prefer to eat fewer eggs that were produced in a better way.

We greatly missed having our own source of dung, as although we could get cow dung from the farm next door, the cows were not fed organically. Even if we did not get very much for the eggs it might be worthwhile to keep chickens for the dung alone, as we had seen how much more powerful it was than cow dung and it would be more organic.

I missed the chickens; I missed the noises they made – their squawking and crowing; I missed their energy.

About six months later, we decided that we would keep a small number of chickens but would do so for what they provided in the way of dung and compost. We would see the eggs as a bonus. We decided to have no more chickens than could be fed from the land, and to keep the local so-called 'village chickens' variety as being the best adapted to the climate and other conditions. Although our other chickens had been fairly well adapted, we suffered a certain amount of disease, and several usually died from heat exhaustion during the hot season. During one very hot afternoon, four chickens died one after the other, despite us spraying the chicken house with water to try and keep it cool.

So far this way of keeping chickens has been very successful. The chickens perform a very important compost-making role, for which we are very grateful. Since we only have a small number of chickens we are able to grow some (but still not all) of their food. The eggs really are a bonus. We are able to charge a premium price for them and they are very much appreciated. We have kept this balance for many years now, and while the number of chickens goes up and down we never have more than can be fed from the Buddha Garden land. As I write this we have fewer chickens than usual, so in the not too distant future we will be buying some more. We have found a chicken shop that sells chickens of the right age, so nowadays when we buy chickens to keep we are stopping them from being killed for their meat.

LIVESTOCK AND FARMING

Is it possible to farm animals in more ethically acceptable ways? Generally, on organic/sustainable farms, the health and well-being of animals are monitored according to the principle of health being defined as a positive physical and mental states, and not just the absence of disease. Positive animal well-being means the satisfaction of all the animal's needs, including its behavioural needs, not just the absence of cruelty.

To keep their animals healthy, organic farmers:

Build up natural vitality and disease resistance by providing the animal a nutritious diet of organic food. There are various methods of rotating the pastures on which the animals graze so that parasites and other diseases are spread less easily. Often internal parasites are species specific, so in order to keep them under control farmers may employ mixed grazing practices. This is where, for example, cattle would graze a pasture one year followed by sheep grazing it the next.

Alternatively, organic farmers may practice **clean grazing** to break the parasite cycle. In this method livestock is moved after a set amount of time to land that has not been grazed by that kind of livestock for several years. For example, a piece of land would be used by pigs for a maximum of six months, and then kept free of pigs for at least four years.

M**inimise stress through good management techniques**, which include providing good housing with adequate bedding on solid rather than slatted floors that can cause foot problems. In addition, the animals should have sufficient space, mobility, and adequate fulfilment of their social needs.

S**elect breeds which are adapted to local conditions and able to resist disease.** The characteristics of many native breeds play an important role in ensuring the positive health of the animals – as we found with our chickens. They include suitability to locality (climate, altitude and soil), hardiness, thriftiness, disease-resistance, a quiet temperament, maternal instinct, and ability to thrive on the local diet. In the most intensive conventional animal farming operations, breeds that tend to be faster-growing as well as producing more milk or meat are used in preference to others. This can put animals under excessive stress, weaken their natural immune systems, and increase reliance on veterinary medicines.

If, despite these precautions, an animal becomes ill, then organic farmers are encouraged to use natural and complementary therapies as a first resort. If these are not effective, then conventional medicines, including antibiotics, must be used. The important thing is that the welfare of the animal is paramount: in other words, if an animal is sick it must be treated. If antibiotics are given to an animal, however, there must be a sufficiently long exclusion period before the produce of that animal can be sold as organically produced food. Generally organic livestock must not be given antibiotics, hormones, or medication in the absence of illness, although in some countries they are allowed to be vaccinated.

AND FINALLY...

There are many arguments for and against whether we should eat animals and whether they should be kept on farms. Sometimes, however, arguments against animals on farms are more a response to factory farming and cruelty to animals, rather than an argument against eating them per se. Perhaps humans need a different relationship with farm animals. It has been suggested that the time has come to envisage a notional contract with farm animals, which requires humans to repay the benefits received from them by ensuring, as far as possible, that they are cared for respectfully and compassionately. In reality, animals in the wild often suffer in worse ways than those raised on farms. To the extent that humans have control over the lives of both farmed and wild animals, there could be said to be a duty for humans to exercise that control wisely and with compassion. Is it possible to give animals a good life and a humane death as part of a fair contract in which they supply us with food?

Many people eat meat, and even vegetarians who consume dairy products, including milk and eggs, rely on animals for food. While many people argue that everyone should be vegetarian or vegan, it is questionable as to whether this could ever happen – unless population or other pressures makes meat production impossible or too expensive for most people. As we look towards 2050, when there will be a need to feed two billion more people on the earth, there is a new urgency about the question of what kind of diets the earth will be able to support for this number of people. Increasingly, the foods we choose to eat in the coming decades will have considerable ramifications for the earth and its ability to support its population. A diet that revolves around meat and dairy – a way of eating that is on the rise throughout the developing world – will take a greater toll on the world's resources than one that revolves around unrefined grains, nuts, fruit and vegetables. In the end, it might just be the pressure on the earth's resources that make it impossible to eat a meat-based diet rather than any philosophical argument. Although as mentioned previously, eating a plant-based diet doesn't necessarily lead to a better environmental outcome. It all depends on what you eat.

WILD ANIMALS

In Buddha Garden we have had to deal with several different sorts of wild animals that come and disturb our crops in various ways. Parrots fly onto and eat our maize, rats and squirrels come and eat our pumpkins and gourds. We try to deal with these animals in a way that limits the damage they create while not disturbing them too much. Covering up the maize with bags deters the parrots, and at times we have had to do the same thing with pumpkins and gourds. If an animal does start eating any of our vegetables we leave it out for them to finish off, so they don't start eating anything else.

Fortunately, we are not visited too much by monkeys or peacocks, which can be extremely destructive. If we ever see them in the garden we run after them with the dogs and make a lot of noise. So far this seems to give them the idea they are not welcome. Although in one of the school gardens we have had to put a net over the whole garden to keep out the peacocks that were eating everything. The larger animals like cows and goats we keep out with good fences.

BASIC STRATEGY FOR LOOKING AFTER YOUR ANIMALS

Animals can be important to farming especially when the soil is very poor. They do, however, need a lot of care, and you have to decide whether you want to do this or not; whether you have the time and energy to look after them; and whether you are willing to take responsibility for them, which might include having to kill them. Remember that you can sometimes borrow someone else's animals or get the dung from them. In this case it would be best if they were fed on organically grown food.

A decision will have to be taken as to how the animals are going to be integrated with other food production activities. Are they going to provide meat? Other food like eggs or milk? Dung?

If you decide not to have any domestic animals you will still maybe have to deal with wild animals interfering with your crops. You will need to find ways of dealing with this that do not disrupt the animal's natural rhythms.

SECTION THREE

BRINGING IT ALL TOGETHER

BRINGING IT ALL TOGETHER AND DEVELOPING YOUR FOOD GROWING PRACTICE

The elements of food growing are the same everywhere, but the way in which you bring them together will be unique to you. When you start the practical process of food growing, it will be up to you to decide how to bring the elements of food production together in a way that best serves you and the place where you are doing it.

Each place presents a different and individual set of circumstances, limitations and possibilities. Resources of time, energy, money and people you have at your disposal, the climate and the physical characteristics of your place, will all play some part in your decisions about how to bring everything together. It is not, however, just the practical factors that are important, but also your vision – for it is this, which is the inner guide. It is my vision that has guided me as how best to bring everything together into a creative whole to start Buddha Garden. A creative whole that has enabled me not only to practically grow food, but also to be in harmony with my deepest aspirations and life goals. It is my vision that has sustained me in difficult situations, and to which I return when I need inspiration or when change seems necessary. But it is the collective vision of everyone who is part of the team here that sustains it now and for the future. How to pass on that vision in a way that keeps it alive for the future is an ongoing process for all of us.

To grow food sustainably is not a mechanical process, but more of a fluid dance between ourselves and nature. It is an art rather than a science, although we need to make use of scientific knowledge where and when it is appropriate to the process. The more understanding we have of the food-growing elements and how they are supported by natural processes, the more we are able to harness them effectively and sustainably. At the same time, we need to be responsive to the land as it responds to how we engage with it, as this will play a large part in how our vision will manifest. As I have gone deeper into the process of growing food, I have found my vision changing according to both how the land has responded to my engagement with it and to changes within me.

As the farm has evolved, I find that each time I write about the history of Buddha Garden I tell a different story. This is not only to include the most recent events, but because my viewpoint on what I have experienced and what it means to me personally and for the farm has changed. Different aspects of the process take on a different significance and consequence. Some things that seemed so very important when we started nearly twenty years ago now seem insignificant, while things that we ignored in the beginning have grown in importance and need more of our attention. I realise – but often forget – that to run a sustainable farm requires that I am personally sustainable. It has been, and continues to be, a very dynamic learning process for me on how to retain a right balance in my life. Growing food has, for me, always been about both producing food as well as coming into a harmonious balance with the land and within myself.

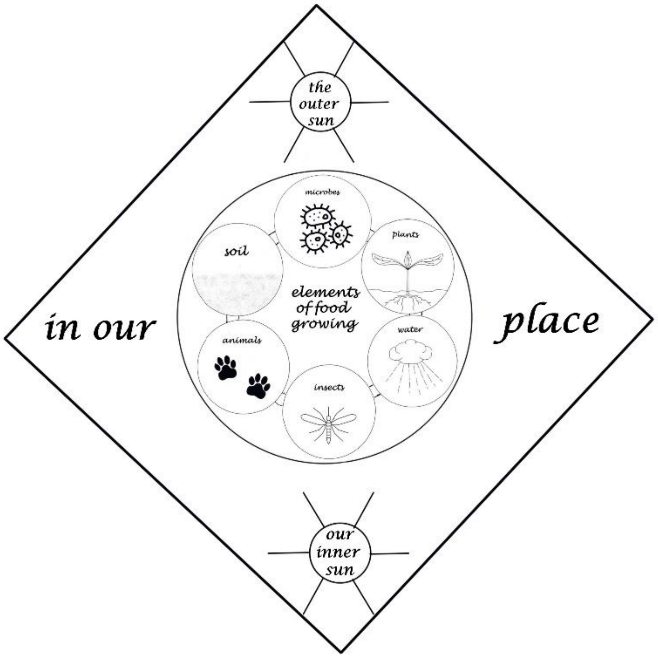
From the very beginning I wanted to run the farm cooperatively with a group of like-minded individuals, but for five years I had to run the farm on my own, as I could find no-one who wanted to do it with me. Despite my aspiration for more people to become involved on a long term basis, this never seemed to happen. After five years I realised that to carry on alone was not a personally sustainable situation. I then decided that unless others came to help (I set a date for this to happen!) I would stop farming in Buddha Garden and do something else. Within three weeks of taking this decision two people turned up, one of whom retained his connection for many years. Gradually other people have come, and now we have a community here with all the challenges and benefits that this brings to each of us.

Over the last twenty three years I have found the land to be a potent teacher. Day-by-day as I have worked in Buddha Garden, various events have triggered issues and feelings that have been a powerful force for my inner growth and creativity. Much of my expression, whether in words or pictures, is rooted in my experience with the land. Like all my teachers, the land is a living entity, and I have learned my farming through engaging with it rather than through books. This is not to say that I have done no reading, but rather that the real learning for me has come through doing the work rather than reading about it.

I have also had considerable help from other farmers in Auroville, who have generously shared with me the results of their experience. One of the best sources of inspiration as well as knowledge and support is to talk to other food growers in your area. Whether they have large farms or small gardens they will teach you much about the process, the practical limitations and possibilities of your place, and inspire you as you find your own path. You might also feel resonance with one or more holistic farming methods/philosophies, which have evolved as part of the emerging modern organic farming movement. Perhaps some of their practical techniques or philosophy will be particularly relevant to you and your situation. Buddha Garden is a good example of the way in which techniques from some of these approaches have been adopted and adapted. The raised vegetable beds are based on the 'bio-intensive methods', and the overall layout of the farm was carried out with the help of a visiting permaculture expert from South Africa. Details of the most well-known holistic farming philosophies and methods are in Appendix 3.

Each place that is used for food growing, however large or small, is unique, and the way that each individual engages with it is also unique. Someone else would have found a different mode of engagement with the land of Buddha Garden, which would then have evolved into a completely different kind of place. To grow food sustainably is to engage in an unending process of both practical work and reflection on that work, so as to keep the necessary balance between all the elements that need to be in harmony for the endeavour to be successful. No one can tell you what you should do in your particular situation, although books and people can provide pointers. You have to decide and then see what works for you. It is like a dance between yourself, the place, and all the other elements that enable us to grow food.

Understanding each of the elements, the natural processes that support them and how best to work with them is a lifelong learning process There will always be more to learn – from books, internet, teachers and other farmers, but the most profound learning is rooted in the practical food growing process. The sum of this learning is what I call 'the inner sun'. The sum of our evolving knowledge, understanding and awareness about the best way to grow food in our place at any one time. It balances the outer light of the sun under which we grow food in Buddha Garden. We work to sustain the earth as the earth sustains us.


the outer sun
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APPENDIX 1: ABOUT AUROVILLE

Auroville draws its inspiration from the work of the Indian spiritual visionary Sri Aurobindo and was founded in 1968 by his spiritual collaborator known as the Mother. Both Sri Aurobindo and the Mother had expressed in their earliest writings the necessity of starting, at some point, a collective experiment – ideally in the form of a city – to create a bridgehead for a new consciousness which was seeking to manifest in the world. The Ashram, formally created in Pondicherry in 1926, was a first attempt in that direction. Here, in 1964, the idea of Auroville was first conceived:

'Auroville wants to be a universal town where men and women of all countries are able to live in peace and progressive harmony, above all creeds, all politics and all nationalities. The purpose of Auroville is to realise human unity.'

The name 'Auroville' was given in homage to Sri Aurobindo, while also having the most appropriate meaning, 'City of Dawn'.

In an inauguration ceremony which took place on 28th February 1968, the Charter of Auroville, written by the Mother, was first heard. For me it is still the most succinct and inspiring description of the ideals on which Auroville is based.

Auroville belongs to nobody in particular. Auroville belongs to humanity as a whole. But to live in Auroville one must be a willing servitor of the Divine Consciousness.

Auroville will be a place of unending education, of constant progress and a youth that never ages.

Auroville wants to be the bridge between the past and the future. Taking advantage of all discoveries from without and from within, Auroville will boldly spring towards future realisations.

Auroville will be a site of material and spiritual researches for a living embodiment of an actual Human Unity.

Auroville is now an emerging international township of over 3,100 people from India and more than 55 other nations who pursue a very wide range of practical activities necessary for its upkeep and development. These include village development, education, land restoration, business, research into renewable energy and experimental construction techniques, health care and varied cultural activities. Whatever the outer activity and material achievements, however, the main aim is inner change. For without an inner change in consciousness no permanent outer change is possible. All practical activities are not merely tasks which are necessary for the functioning of the township, but opportunities for bringing consciousness into matter and with it the possibility for a new way of being to emerge.

APPENDIX 2: PLANTS AND THE CYCLES OF LIFE ON EARTH

Plants participate in cycles that are crucial to our life on this planet. The Earth is sometimes referred to as a closed eco-system, because all the materials necessary for life are here, so it must continually recycle all existing materials for life to continue. There are three main cycles of life in which plants play a crucial role.

We have already described the **water cycle** whereby water on the earth's surface continually evaporates, condenses in the sky as clouds, and falls again as rain, snow or sleet. Plants are an important part of this process as they release water through transpiration, a process in which water vapour is given off through leaves and into the air. In places like the Amazon rainforest, plant cover is particularly important to absorb the huge amounts of rain water that it later releases back to the atmosphere. Cutting down the rainforests disrupts the water cycle, with the initial consequence that soil erosion is increased because there is no vegetation to act as a "buffer" to hold the water in the plants and soils. Another probable consequence is a long-term and irreversible decline in available water in the region. An area as vast as the Amazonian rain forest recycles a great deal of rainfall back into the atmosphere by transpiration from the leaves of plants. If the forest is removed, rain will run off to the sea via river flow, as has been demonstrated in places where forests have been totally cleared. Evaporation of sea water will of course return fresh water to the atmosphere, but it is very unlikely that the Amazon rain forest will receive much of that rainfall. The climate of the Amazon region will become drier, and it is questionable whether a humid tropical forest would ever be able to re-establish itself.

The **carbon cycle** is the sequence by which carbon that has been extracted from the non-living earth is recycled amongst living beings. The concentration of carbon in living matter (18%) is almost 100 times greater than its concentration in the earth (0.19%). Carbon exists in the non-living environment as:

carbon dioxide (CO_2) in the atmosphere and dissolved in water;

carbonate rocks (limestone and coral = CaCO3);

deposits of coal, petroleum and natural gas derived from once-living things;

dead organic matter e.g. humus in the soil.

Carbon enters the living world through the action of so-called autotrophs. These are mainly plants and algae which, during the process of photosynthesis, use the energy of light to convert carbon dioxide from the atmosphere to organic matter.

There are a small number of bacteria who carry out the same process – converting carbon dioxide to organic matter, but they do this through a process of oxidation (oxygen combines in their molecules) rather than photosynthesis.

Carbon returns to the atmosphere and water by:

respiration (as carbon dioxide);

burning of wood and coal;

decaying of natural substances (produces carbon dioxide if oxygen is present and methane, a gas, if it is not).

The carbon dioxide content of the atmosphere is gradually and steadily increasing since the late nineteenth century when measurements began. Recent research has shown that its concentration has risen approximately 42%. This increase in carbon dioxide can be related to:

Burning fossil fuels (coal, oil, natural gas), which contain carbon that has been locked within the earth for millions of years. This process releases the carbon into the atmosphere as carbon dioxide;

Clearing and burning of forests, especially in the tropics. In recent decades, large areas of the Amazon rain forest and in south-east Asia have been cut down to make room for agriculture and cattle grazing.

Curiously, the increase in atmospheric carbon dioxide is only about one-half of what would have been expected from the amount of fossil fuel and forest burning. So where is the rest? There is some evidence that the missing carbon dioxide has been incorporated by:

increased growth of forests, especially in North America;

increased amounts of phytoplankton in the oceans.

Despite these so-called "sinks" for our greatly increased carbon dioxide production, the concentration of atmospheric carbon dioxide continues to rise and contributes to global warming. Carbon dioxide is transparent to light but rather opaque to heat rays. Therefore, more carbon dioxide in the atmosphere retards the radiation of heat from the Earth back into space, causing the "greenhouse effect" whereby the earth as whole gets warmer. The rise in carbon dioxide concentration and whether it is related to human activity is a much-debated issue. While the majority of climate scientists think there is a connection, there is still a minority who disagree. Although the relationship between increased carbon dioxide levels and the temperature of global warming is complex, there is a ground swell of opinion, backed by science, that unless humans take decisive measures in a number of areas – energy, food production and forest/ocean protection – earth will become uninhabitable for the next generation.

The **nitrogen cycle** is a complex cycle essential to life, because although there is a lot of nitrogen in the air it cannot be used by plants and humans in this form. To be useful, this nitrogen has to be 'fixed' so that it becomes available first to plants, which absorb it, and later to animals and humans who eat the plants. Animals secure their nitrogen (and all other) compounds directly from plants (in the case of herbivores) and indirectly through other animals that have fed on plants (in the case of carnivores).

Nitrogen fixation takes place in the following ways:

Atmospheric fixation: During a thunderstorm, the enormous energy of lightning breaks nitrogen molecules and enables their atoms to combine with oxygen in the air, forming nitrogen oxides. These dissolve in rain, forming nitrates that are carried to the earth. Atmospheric nitrogen fixation probably contributes some 5–8% of the total nitrogen fixed;

Industrial fixation: Under great pressure at a temperature of 600°C and with the use of a catalyst, atmospheric nitrogen and hydrogen (usually derived from natural gas or petroleum) can be combined to form ammonia (NH3). Ammonia can be used directly as fertilizer, but most of it is further processed to urea and ammonium nitrate (NH4NO3);

Biological fixation: This is carried out by the action of bacteria on the roots of plants. The bacteria combine gaseous nitrogen and hydrogen to make a chemical compound called ammonia, which the plants absorb. Decay also produces ammonia, that through a process known as nitrification converts the ammonia to nitrates and nitrites, which can be absorbed directly by plants.

The nitrogen cycle is complete when the left-over nitrates and nitrites in the soil are reduced to nitrogen gas that again replenishes the atmosphere.

Once again it seems that human behaviour has caused nitrogen overload in various parts of the ecosystem, with dramatic consequences:

- The use of large amounts of inorganic nitrogen fertilizers in agriculture, and the dumping of enormous quantities of raw sewage from urban settlements, create colossal amounts of nitrogen to run into rivers, lakes and the sea. This creates an excess of nutrients which causes algae to bloom. The algae rapidly deplete all of the oxygen in the water, making it inhospitable for fish and other aquatic organisms. This process of water bodies dying is known as eutrophication;
- When plants are saturated with nitrogen, the run-off water after rainfall gets contaminated. This makes the soil too acid, which greatly reduces its fertility;
- Burning fossil fuels and wood contributes huge amounts of nitric oxide to the atmosphere. Nitric oxide can combine with oxygen gas to form nitrogen dioxide, which reacts with water vapour to form a strong acid (nitric acid). This precipitates out of the atmosphere in the form of acid rain, which damages trees and kills fish.

When we grow plants organically, we not only produce food but we also participate in these cycles, but usually in very positive ways.

APPENDIX 3: SOME HOLISTIC APPROACHES TO SUSTAINABLE FOOD GROWING

BIO-INTENSIVE METHOD OF FOOD GROWING

Bio-intensive organic gardening has its roots in the French market gardens of the 19th century. Parisian gardeners at this time were able to grow over 100 pounds of produce annually for every person in the city. They achieved this remarkable productivity through the use of raised beds (up to 18 inches in height) built with horse manure, which was abundant at the time, close plant spacing, and the use of glass cloches to allow for growth even in the winter. These techniques were brought to the United States by Alan Chadwick in the 1930s, and have continued to be refined and promoted by John Jeavons and J. I. Rodale in America. While some farms use these methods, it has been particularly promoted to 'back yard' gardeners who want to grow some or all of their own food.

A key element in intensive organic gardening is the raised bed, which is made of loose rich soil that provides excellent growing conditions for most vegetables. Initially they are made using a process known as 'double digging', where the soil is loosened to a depth of two spade lengths and compost is added in a systematic way as the digging progresses. Once made, the beds need little attention apart from being turned and composted at the start of each growing season.

The second most important element in this type of organic gardening is a close planting pattern. This shades the soil, keeping it cool and moist for good root growth, and discourages the growth of weeds. Intercropping is also used with, for example, carrots and lettuces. The lettuce shades the soil and keeps it moist, allowing for easier germination of the carrot seedlings. Then, when the lettuce is harvested for the season, the carrots will grow up and fill the space. Through intercropping, two or more crops can grow in the same area of a bed in a single season.

To maintain the fertility of the soil various measures are used:

Crop rotation involves alternating plantings between those plants that feed a lot and those that don't. It includes using soil building crops such as beans and other legumes which fix nitrogen in the soil.

Composting is a process that involves the breaking down of organic materials in a bin or pile to provide organic matter and more organisms in the soil, to make it easier for the plants to absorb the necessary nutrients.

Additional fertilization is usually in the form of 'liquid manure' or 'compost tea'.

Pest management is carried out by:

Ensuring that the soil is healthy as healthy plants growing in a healthy soil are more resistant to pests.

Rotating crops so that pests are unable to multiply in the soil.

Growing a variety of crops and focusing on those that grow well in the climatic conditions of the garden.

Companion planting so that one plant will keep pests off another plant. Or plants that attract the pests are grown so that pests go there rather than feed on the crops.

Covering the plants with nets.

Using traps and manually removing pests from plants as soon as they are seen.

To find out more read any books by John Jeavons. The most recent one is *How to Grow More Vegetables: And Fruits, Nuts, Berries, Grains and Other Crops Than You Can Imagine*.'

BIODYNAMIC FARMING

'Biodynamics is a science of life-forces, a recognition of the basic principles at work in nature, and an approach to agriculture which takes these principles into account to bring about balance and healing. In a very real way, then, Biodynamics is an ongoing path of knowledge rather than an assemblage of methods and techniques.'

From *An Introduction To Biodynamic Agriculture* by Sherry Wilfeuer.

Based on the work of Rudolf Steiner, biodynamic farming is part of an approach to the world known as anthroposophy. This approach offers an account of the spiritual history of the Earth as a living being, describing the evolution of humanity and nature. Within this context farmers need to become aware of all the things that affect plant growth. This includes not only the material soil, air and water, but also more subtle influences such as the position of the moon and the stars.

There are regular rhythms to these influences, and biodynamic farmers use these rhythms by timing their farming work – preparation of the soil, sowing, cultivating – for the best advantage of the crops being raised. The method requires careful and extensive observation of nature, until the farmers are at a point where they can 'read' nature and take the necessary steps that will optimize the growth of plants. There are also calendars which help them do this.

Biodynamics recognizes that the soil is alive and that it is the vitality within the soil that affects the quality and health of the plants that are grown. Farming biodynamically means building up a vitalized soil with abundant organic matter obtained by making and applying compost. The plants thus grown will have more energy within them which will improve the vitality of the humans who eat them. Biodynamic farmers believe that the process of chemical agriculture – whereby plants take up soluble minerals that have been put in the soil – bypasses the very necessary process of the plant seeking the minerals from the soil themselves. Such plants, which have been artificially stimulated, have less vitality than plants grown bio-dynamically, and soil treated in this way with chemicals also becomes less alive.

Various preparations are used to focus and stimulate cosmic energy. Naturally occurring plant and animal materials are combined in specific recipes and placed in compost. These preparations have concentrated forces within them which organize the elements of the compost and result in medicines for the Earth, drawing new life forces from the cosmos.

'Biodynamics' published by the Bio-dynamic Farming and Gardening Association of New Zealand is a good introduction to the practice of biodynamic farming. Rudolf Steiner gave a series of talks to farmers about biodynamic methods, but they are difficult to understand if you don't understand the underlying philosophy. Anyone seriously interested in practicing this method needs to read and digest all that Steiner wrote, both about the philosophical/spiritual basis on which bio-dynamics is based as well as the practical advice he gave in his lectures on agriculture.

NATURAL FARMING

Natural farming is based on working with natural energies rather than trying to conquer nature. It is distinct from organic farming that is simply a return to the agriculture of the pre-chemical age.

Understanding the soil is central to natural farming, as it retains the fertility of the soil by growing food in a way that does not require any external inputs or disturbance such as ploughing or digging.

For over 50 years the Japanese Masanobu Fukuoka developed a method he sometimes calls 'do-nothing agriculture', which requires no ploughing, digging, weeding, composting or any kind of pesticides. He grows seasonal crops, rice in summer, and barley and rye in winter. He uses just the scattered straw of the preceding crop, a cover of clover, and an occasional sprinkling of poultry manure for fertilizer. Instead of planting seeds and transplanting seedlings as in traditional rice cultivation, Fukuoka simply scatters earth and clay pellets containing seeds onto the ground. Then he floods his fields, but for a much shorter duration than the usual rice farmer. The flooding is timed to be done after the barley harvest, while the clover is still very thick and the rice is just getting started. This weakens the clover and other weeds but does not slow the rice down. Rhizobium bacteria that live in association with roots of the clover break down atmospheric nitrogen, some of which is supplied to the growing rice plants. As in many natural ecosystems, the nitrogen-fixing plants used in this method are the major source of nitrogen, which is the most important nutrient for plant growth.

Other forms of natural farming include tropical forest gardens, a system which mimics natural forest vegetation using edible and other useful plants to fill each niche. This idea has been adapted to temperate climates. Once established, such gardens are diverse and productive growing systems which need little maintenance work. There are also mixed farming systems where livestock plays an integral part in maintaining the agricultural ecosystem. Often these have been developed by traditional farmers to make the most efficient use of small areas of land. The key to growing vegetables in natural farming is to use local varieties of edible wild plants, utilizing as wide a variety as possible and growing them in a way that enables them to self-seed.

In adapting methods of natural farming to temperate climates it is necessary to investigate a wider variety of grains and vegetables to be grown. It is also better to use crops that are perennial rather than annual and that are well-adapted to the local area.

Part of the ethos of natural farming is that it is an activity which enables us to develop ourselves, to restore and maintain our health and well-being as well as reconnecting us with the earth. It is a philosophical way of being rather than just a set of techniques.

This was described in his book *The One Straw Revolution* and further elaborated in *The Natural Way of Farming* by Masanobu Fukuoka.

PERMACULTURE

Permaculture or 'permanent agriculture' focuses not only on agriculture but on all aspects of human living, and seeks to find a way for humans to live sustainably on earth by imitating natural sustainable processes. Permaculture is about a way of living that focuses on integrating inputs and outputs in a sustainable way, rather than following a set of prescriptive rules in a superficial manner.

In practice a permaculture project employs the diversity, stability and resilience of natural ecosystems to provide a framework and guidance for people in developing their own sustainable solutions to the problems facing them on a local, national or global scale. It is based on the philosophy of co-operation with nature and caring for the earth and its people.

A system of design requires 'maximum contemplation, minimum action' to find mutually beneficial relationships and translate these into action. The life or project must therefore be seen as a whole system – working out the most effective way to do things that involves the least effort and damage to others. All the available resources and the way they relate to each other have to be carefully examined before action is taken. A key feature of permaculture design is 'zoning', which means placing things in the right place to maximise effort and resources wisely.

Permaculture principles also focus on sustainability and fairness in terms of:

Earth care – with sustainable systems that work with nature.

People care – which includes caring for ourselves individually as well as communally.

Fair shares – limiting our consumption so that everyone has access to the fundamental needs of life – clean water and air, food, shelter, meaningful employment, and social contact.

Permaculture seeks to foster the skills of self-reliance and increased self-sufficiency within the community. As a versatile concept, however, it can mean different things to different people. One person may interpret permaculture in a practical sense in terms of growing food, while another may focus on its more spiritual dimension. This diversity is important as it helps to instil a sense of balance, and encourages people to share their resources and knowledge with others. Working together is the key factor in successful permaculture living and farming.

A good start is to read *Introduction to Permaculture* by Bill Mollison, Reny Mia Slay and A Jeeves.

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ABOUT THE AUTHOR

PRIYA VINCENT

Priya Vincent was born and educated in the UK and has worked as a nurse, radiographer and teacher. She received her doctorate in sociology from the University of Surrey (UK) and subsequently worked for fifteen years in various market research companies. After the birth of her second daughter Emma, she went to live with her partner in Malaysia where her third daughter Rachael was born. There she took the opportunity to change direction and carry out research on traditional midwifery and published a number of books on the subject. After living in Yemen and Malawi she came to Auroville in 1996.

Priya started Buddha Garden in 2000 and is still involved with the day-to-day practical work. Recently Auroville has decided that it needs a new VIP road and car park and that the land of Buddha Garden is needed for this. Efforts to try and find an alternative location in Auroville and move the farm there have not, so far (2023) come to any positive conclusion. Over this period someone who was once a volunteer in Buddha Garden has asked me to help him set up a farm in Malaysia. I find this a very interesting ongoing opportunity to implement the approach described in this book!

Since the demise of Buddha Garden in its present incarnation is likely to happen quite soon I have set up an online presence at http://earthfriendlyfoodgrowing.com

Here you can sign up to receive a regular daily blog, read longer more reflective pieces about food growing work as well as purchase interesting digital and print books. You can also connect with me on various social media and enjoy a weekly video on the YouTube channel Earth Friendly Food Growing.

You can contact me on earthfriendlyfoodgrowing@proton.me