CHAPTER ELEVEN

# *Growing Leaf Vegetables*

## WHY GROW YOUR OWN LEAF VEGETABLES?

Industrial agriculture has become an increasingly secretive and specialized endeavor, with fewer people working on larger, highly mechanized farms. One of the best things about sustainable agriculture is that everyone can participate. The most rewarding place to participate in sustainable agriculture is often in the household vegetable garden, and leaf vegetables are usually the easiest food to grow.

There are several good reasons to grow some of your own leafy vegetables even if you can easily afford to buy all of them.

### *Quality Control*

The flavor of home grown, fresh picked vegetables is widely experienced as superior. For example, commercial packers consider the shelf life of spinach to be 10–14 days, but both the flavor and the nutritional value are significantly better just after picking. Home gardeners can make sure that their vegetables are not only fresh but free from pesticide residues. Where refrigeration is limited, the freshness of home garden greens is a big step up from commercial greens.

### *Variety*

There are very few commercial leaf vegetable varieties that are widely available and they are chosen exclusively for profitability. Traits such as high yield, uniform harvest time, response to herbicides and fertilizers, and the shipping qualities of leaf vegetables are important to the commercial packers. They rarely coincide with the best flavor or nutrition. On the other hand, home growers have access to a vast array of delicious and nutritious crops and varieties.

### *Economy*

For many families whose income depends on unemployed, underemployed, or poorly paid workers, having access to some food outside the cash economy can be very advantageous. The number of families in this situation is high in the tropics and will likely continue to grow, as will the benefit they derive from home-grown leaf vegetables. Hard times invariably result in more home vegetable gardening. In the US the economic hardships brought on by World War II were partially offset by the success of the Victory Gardens campaign, which produced roughly a third of all American vegetables that were consumed.

### *Ecology*

Leaf vegetables are generally 80–95% water. Growing them in semi-deserts with irrigation and shipping them thousands of miles in refrigerated trucks is a bad idea. Locally grown vegetables are far more environmentally sound, even when grown out of season in protected hoop houses. Home grown are the most local of all, eliminating even the drive to the market.

***Emotional and aesthetic benefits***
Gardens can be beautiful places offering enjoyable physical exercise, relaxation, and connection with creative natural forces.

## WHERE CAN YOU GROW LEAF VEGETABLES?

It is not hard to find a place to grow leafy green vegetables because they will grow almost anywhere that humans have chosen to live. Green leafy vegetables can be grown on any scale from a box in a sunny window to vast fields of alfalfa. The best place to grow greens is usually in a home garden located as close to family activities as possible. For several reasons this book focuses on home gardens. Typically these range from the size of a couch, or even a few containers, to about the size of a basketball court (approximately 2–500 sq m or 20–5,000 sq ft).

Households that don't have own or have access to any land need not be shut out of the vegetable growing experience. There are about 16–20,000 community gardens operating in the US as of 2009; and similar community-based gardening opportunities exist in many other countries. Most of them lease vegetable plots at very low cost. Many offer beginner classes in gardening and some have established systems for exchanging seeds and sharing tools. The movement to create community gardens is growing as urbanites continue to express their interest in raising food. The size of community garden plots varies a great deal, with an average of about 28 sq m (300 sq ft), but even the smallest plots have space enough to grow dozens of servings of greens for a family. A good resource in the US for learning more, including help with finding a garden near you, is the American Community Gardening Association.

Another movement that promises to create thousands of new vegetable gardens started in 2008 in England. This movement is promoted by the organization Land-Share and several other similar groups. These organizations are trying to expand on the British tradition of the vegetable plot, by linking people interested in gardening with people who have some unused or underused land available. Often this is a win-win situation as property owners typically benefit from the care that gardeners give to their vacant land. It is a popular concept in England where nearly 200,000 people are on long waiting lists for small garden allotment plots. Land-Share began as a spin off from a gardening show on television. By the summer of 2010 it had more than 54,000 members. Neighborhood associations and municipal governments are also becoming more aware that where land is cared for by gardeners, vandalism and crime often diminish.

On an even smaller scale of operation, greens can be grown in containers. These can be almost anything that will hold a few inches of soil and that can be placed in the sunlight for most of the day. Many greens are ideally suited to container growing because they are relatively small plants with shallow roots that are highly adaptable, fast growing, and produce more food in a given space than most other crops.

## FARMS AND GARDENS

We currently get almost all our foods from farms. Farms are primarily agricultural businesses designed to make money. They run along a continuum from large gardens that produce a surplus that can be sold at local farmers' markets to gigantic, corporate-owned food production operations. At the small end of this scale are subsistence farmers, part-time farmers, and families trying to supplement off-farm income by selling some of the extra food that they grow. Also on this end of the farm spectrum is the growing phenomenon of CSAs (Community Supported Agriculture). These are generally small farms that link with consumers who pay an annual subscription fee and receive weekly boxes of produce.

There is growing interest in obtaining fresh local food that is produced in a manner that exploits neither the land nor the farmer. The small scale growers who, against all odds, are producing top quality food at a reasonable cost while truly caring for their land are a small and heroic lot. Unfortunately these well-cared-for small farms are not currently the origin of most of our food.

The bulk of our food is grown on large farms that suffer from the same reductionist economic philosophy as other modern businesses. As a rule, producing food as cheaply as possible doesn't happen on Rebecca's Sunnybrook Farm or Old MacDonald's farm, populated by cheerful animals. Modern farms are increasingly brutal biological factories, where beauty and love of the land, plants, and animals have no home. No one will have fond childhood memories of growing up on a farm with 4,600 hogs or a quarter-million chickens. No one will pine for the laser-planed fields of California's Imperial Valley and its crews of migrant workers picking their way down mile-long rows of identical cabbage.

Compared to big farms, gardens tend to have much smaller fields but much larger mandates. Rather than existing solely to generate cash, one might realistically expect a garden to provide recreation; beautiful flowers for the table; a home for songbirds, frogs, and turtles; physical exercise and communion with Nature, in addition to a wide variety of fresh food. Gardens are typically deeply loved, sorely missed and fondly remembered. The smallest of farms often have more in common with gardens than with large farms.

Gardens can address many of the shortcomings that big commercial farms impose on our food system. Because gardens are smaller and rarely a critical source of income, gardeners can afford to experiment where farmers often cannot. They can grow different varieties of crops, not just the varieties that are the most profitable or that ship with the least damage. A cornucopia of heirloom plants, each with distinct taste and attributes, is kept alive by gardeners, long after farmers abandoned them for more profitable hybrid and genetically modified crops. Agricultural biodiversity is increasingly the domain of the garden rather than the farm.

While farm yields have increased dramatically over the past century, much of the upsurge in food production has been brought about through increasing the capital and energy available for farming. Farmers have been consolidating land holdings into larger units in order to justify borrowing the capital to invest in larger machinery. Cheap energy, mainly in the form of petroleum and natural gas, runs the big tractors and produces the synthetic fertilizers and pesticides that power the bigger farms. While farm yields are still increasing, the rate of increase is slowing. More problematic is that the cost of farm inputs per each ton of additional yield is increasing faster than the yield (the Law of Diminishing Returns), and this drives even more farmers out of business.

The Law of Diminishing Returns describes how a continuing effort toward a goal tends to decline in effectiveness after a certain level of success has been reached. For instance, installing a sink in a home that lacks one has a significant benefit. Installing a second sink costs as much as the first to install and has a noticeable but smaller benefit. The third sink has a minimal benefit. The fourth sink has a negligible benefit. All further sinks are likely to have no benefit at all, but will have the negative impact of requiring cleaning and maintenance, even though each sink cost the same to install as the first one.

Another example might be a goal of saving fuel by making your automobile more efficient. Assume your car currently will go 10 km per liter (23 miles per gallon) and your goal is to go 100 km per liter (230 miles per gallon). Improving efficiency from 10 to 20 kilometers per liter (46 mpg) will save more fuel than improving efficiency from 20 to 100 kilometers per liter. Driving 1000 kilometers at 10 km per liter requires 100 liters of fuel. At 20 km per liter only 50 liters are required, a savings of 50 liters of fuel. At 100 km per liter only 10 liters are needed, a saving of only 40 more liters than at 20 km per liter.

This principle is critical to making sound policy decisions towards creating a sustainable food system. In nutrition, there is much greater health benefit at a lower cost providing a child with a poor diet an adequate one than there is providing a child with an adequate diet an excellent one. In agriculture, improving soil fertility from poor to adequate has greater payoff

than improving from adequate to excellent. While excellence remains a worthy goal, our efforts should start with looking for ways to bring the poor up to adequate. Perfect is largely unattainable. Pretty good is great.

There is very little unused good farm land left anywhere in the world to be newly exploited for food production. Land prices near population centers are too high for farming, so farms have moved away from the people, and the food must be shipped ever longer distances to our tables, as the energy costs to ship that food steadily increase.

The situation with gardens is quite different. Gardens are always near where people are, and towns are most often located on good level coastal and river valley agricultural land. There is still plenty of land available to be added to the global gardens. Almost every town has vacant lots and school yards that could be converted to community garden plots. Often the land surrounding a home has enough land to make a productive food garden. In the US, for example, the average lot size is nearly 700 sq m (7,000 sq ft) greater than the average size of the house that sits on it. A vegetable garden using even one-tenth of that extra land can produce enough to improve the health and food security of most families.

Because gardens are almost always within walking distance, the food is usually fresher and requires less energy for transporting than food from farms. Farmers normally must sell their products at low wholesale prices to middlemen who receive the bulk of the price the consumer pays for food. Gardeners, on the other hand, usually grow products that replace food purchased at full retail price. This means a tomato grown by a gardener is often worth several times more than one grown by a farmer.

Gardeners generally get higher yields per area than farmers because they can afford more labor-intensive management. For example, commercial leaf crops are usually cut just once because of the high labor cost of harvesting. Gardeners have the luxury of cut-and-come-again leaf crops which invariably yield more food from the same area.

Perhaps the most important advantage of gardens over farms is an ecological one. Gardens are typically small polycultures because families like to eat a variety of foods. Farms are usually large monocultures because of the cost of specialized equipment and the economic restraints of the market. Polycultures are inherently more complex and stable than monocultures, and more closely resemble a functional natural ecosystem. They have a far greater biodiversity both above and below the soil, and this provides for a wider range of checks and balances against environmental disruptions such as floods, droughts, and infestations.

Although we currently get almost all our food from farms, gardens may actually offer more potential benefits to low-income families and people suffering from malnutrition. Food produced in family gardens is less affected by the political and bureaucratic problems and fluctuating prices for agricultural commodities that often accompany malnutrition.

The price of the land, energy, and equipment needed to be an economically competitive farmer has increased to the point of excluding the poor. On the other hand, the cost of obtaining the information needed to be an effective gardener has plummeted, thanks in part to the growth of the Internet. Operating largely outside the pressures of the marketplace, the home garden can be targeted to meet the family's need for missing nutrients not easily purchased. Fresh foods rich in iron, calcium, potassium, magnesium, vitamin A, vitamin C, vitamin K, folate, dietary fiber and a wide range of protective antioxidants can be easily produced in a small garden.

Knowledge is power, and knowing more about nutrition and gardening is power that low-income families can quickly turn into better health. Starting gardens can be very inexpensive. For example, Helen Keller International's Homestead Food Production program estimates that it costs them only $9 US to start each home nutrition garden. The gardens strengthen

the role of the women who grow them in their communities, increase the amount of vegetables those families eat, and reduce the incidence of night blindness among the children.

By now you might be thinking, "Fine. Gardens are swell, but does anyone realistically think they can feed nine billion people?" No doubt we'll still need big farms for a while; and some crops, such as grains, may always do better on a larger scale. Gardens alone may not be able to feed the billions. However, a major effort to educate and encourage millions of new gardeners would do wonders to improve the stability of food producing environments and the food security of families and communities.

## LEAF GARDEN BASICS

There is a wealth of practical information on all types of vegetable gardening available from agricultural extension services, universities, Master Gardener programs, books, and websites, some of the best of which are listed in the appendix. This section briefly explains the basic principles and techniques of growing leafy greens in a garden. Much of the information could be applied to growing other food and ornamental plants as well.

### *Site Selection*

Vegetable gardens are a means of turning sunshine into food, so try to choose a site that is in the sun all day long. In the tropics, where sun is intense, partial shade may be tolerated. For most leaf crops, heavy shade from buildings or trees will result in weak spindly plants, increased disease problems and low yields.

Choose a location that is as level as possible because level land retains water and nutrients better than sloping land. Land that slopes more than 7% is usually unsuitable for crops because rain can cause serious soil erosion. Level terraces can be built to make sloping land acceptable for gardening, but terrace building is a rather labor intensive endeavor, except on the smallest scale.

Select a location for your garden as near to your home as is feasible. It is far easier to provide good care to a garden you pass by several times a day than a more distant one. Avoid places that are always damp, where animals roam or children romp, and where the soil is likely to be contaminated by sewage, garbage, vehicle exhaust or old lead paint.

### *Garden Layout*

Perhaps the most efficient garden arrangement uses permanent raised beds. These are garden beds usually about 120 cm (48 in) wide and 20 cm (8 in) high. The soil height can be raised by adding dirt dug from between the beds and by adding compost and manure. Raised beds can be planted earlier in the spring because the soil in them warms earlier and waterlogging from spring rains is less of a danger. Raised beds allow better soil drainage and root penetration, because the soil in them is never compacted by people walking on it. The initial investment of labor is quickly repaid in easier cultivation and better yields. There are numerous variations, but all raised beds greatly increase the number of plants that can be grown in a given area and produce much better yields than traditional row crops.

In very sandy soil or in very hot and dry climates it is often better to employ a system of permanent garden beds as described above, except that the beds are not raised but are level with the adjacent ground or even sunken a bit. In these beds the drainage of rain or irrigation water through the root zone is slower than in raised beds making it more available to the crops. Surface evaporation is also slower in a sunken bed, conserving scarce moisture.

An important aspect of garden layout is making sure that your plants have access to as much sunlight as they need. The gardener can improve access to sunlight for plants with a natural climbing or vining habit by using trellises. These are physical supports that enable plants to grow vertically and harvest sunshine that might otherwise be blocked. Crops with edible leaves that thrive on trellises include vine spinach, butterfly peas, pole beans, winged beans, hyacinth beans, yard-long beans, chayote, sweet potatoes, and most gourds.

One of the simplest steps to ensure that your plants get enough sunlight is

arranging the garden so that taller plants are to the north, so that they don't block the critical midday sun of shorter plants. The sunlight of early morning and late afternoon has much less harvestable energy than the sunlight between 9:00 a.m. and 3:00 p.m., so shade in the middle of the day has more negative impact on plants than shading early and late in the day. Of course, the situation is reversed in the southern hemisphere where taller plants should be on the south side of the garden.

## IMPROVING THE SOIL

Soil is a critical component of growing leaf crops and one that the gardener can exert some control over. While crops can be grown hydroponically, without any soil, it is almost always more difficult and more expensive. Virtually every garden soil can be improved in such a way as to benefit the growth of your leaf crops. This is perhaps the most fundamental work of the gardener or farmer. There are some actions that will speed the improvement of the soil, but building really excellent garden soil usually takes ten years or more. As the soil improves it becomes easier to get better yields with less work, so there is a built-in motivator for improving soil. Leaving agricultural soil in better condition than it was in when you started growing is an act of love for the future.

Many growers rely on soluble synthetic fertilizers to improve their soil. They are easy to apply and often provide dramatic results, but they are expensive, disrupt the balance of beneficial soil bacteria, and can ultimately deplete, rather than improve, the soil. Better choices for improving the fertility of your garden are composting, using cover crops and intercropping.

## HOW FERTILIZER LINKS NUTRITION AND ECOLOGY

Commercial fertilizers all have a three-part number, 20-10-10. This number tells us what percentage of the fertilizer is nitrogen, phosphorus, and potassium (N-P-K), respectively. Although potassium is needed in fairly large amounts by plants, it is rarely the limiting factor in their growth. The availability of nitrogen and phosphorus in the soil, on the other hand, often determines the health and yield of a crop. Understanding how these two essential plant nutrients move through our food system is essential as we make a transition to a more ecologically viable way of feeding ourselves.

### *Nitrogen*

Nitrogen is needed by every living cell. It is the chemical backbone of all proteins and proteins are at the heart of life. Proteins are essential to photosynthesis, DNA, RNA, all of the thousands of enzymes, and all of the muscles, including the heart. Without nitrogen there could be no plant growth, no animals or even bacteria.

Unlike phosphorus, nitrogen is in plentiful supply. Surrounding the entire Earth is a blanket of air which is mainly nitrogen.[1] The snag is that animals, including humans, are incapable of using this atmospheric nitrogen for vital proteins[2] until plants have incorporated it into foods. And plants cannot make use of nitrogen from the air until it has been converted, or "fixed," to ammonium or nitrate. This conversion requires a great deal of energy. These facts, when taken together, help explain why foods rich in proteins are usually expensive and why available ammonium or nitrate in the soil often limits food production.

Around 1915, two German scientists invented an industrial process for synthesizing ammonia from natural gas. Called the Haber-Bosch process, this invention radically changed how we produce food. The industrial nitrogen fertilizer gave a big, fast boost to plant growth; and yields of most foods, especially grains, rose quickly. It also reduced the farm labor required as it

1 The Earth's atmosphere is roughly 100 km (62 mi) thick, though most of its mass is in the bottom 8 km (5 mi). The atmosphere is comprised of c. 78% nitrogen; 21% oxygen; 1% water vapor: 1% argon; and 0.384% carbon dioxide. It is widely considered that the carbon dioxide content in the air should be held at about 350 parts per million (0.350%) or lower to prevent global warming and sudden climate change

2 Protein molecules are about 6.25% nitrogen, so you can calculate how much nitrogen is in a product such as soy meal or cottonseed meal by multiplying the crude protein by 0.0625. Soy meal is about 44% crude protein, or 2.75% nitrogen.

was much easier to spread the new fertilizer than to spread the old manure. Industrially synthesized nitrogen fertilizer has been at the center of the fourfold increase in the world's grain production during the twentieth century, which has kept the world's burgeoning population more or less fed.

Before Haber-Bosch, atmospheric nitrogen had always been fixed by special bacteria on the roots of legume family plants, by some primitive blue-green algae, and by lightning. Lightning is the traditional crowd favorite, but has proven difficult to manage for agricultural use. Once the nitrogen from the air is fixed it is incorporated into plant tissue, then eaten by animals, then vigorously recycled through the ecosystem. Eventually it could be lost by leaching, run-off or volatilization (returning to the air as a gas).

The convenience of industrial nitrogen fertilizer is increasingly being offset by the cost of the energy required to make it. While leguminous plants and the rhizobia bacteria[3] on their roots fix nitrogen in the soil at temperatures between 10–32° C (50–90° F), the Haber-Bosch process requires temperatures around 500° C (930° F) and at 200 times atmospheric pressure. Because of the roughly 10,000 kilocalories[4] of energy required to make and distribute every pound of nitrogen, synthetic nitrogen fertilizer is the biggest single energy cost in the entire food system. Almost all of that energy comes from non-renewable natural gas. Burning the gas increases carbon levels in the air and aggravates global warming.

In addition to the extreme energy demands of producing industrial nitrogen fertilizer, there are several drawbacks to using the fertilizer after it has been manufactured. Although plant growth is visibly stimulated by the soluble nitrogen, the organic matter and biodiversity of the soil that the plant grows in are diminished by its continual use.

Like the soluble phosphorus fertilizer, nitrates may be carried by rain, irrigation, or leaching through the soil into surface waters or into underground water reservoirs. The excess nitrates contribute to the over fertilization (eutrophication) of surface water. Nitrogen fertilizers can also contaminate wells and cause dangerously high nitrate levels in drinking water. The elevated nitrate levels can lead to a potentially fatal blood disorder in infants called methemoglobinemia, or "blue baby" syndrome, in which the blood's capacity to carry oxygen is diminished.

Even the soluble nitrogen fertilizer that reaches and is absorbed by the root of the target crops can have some negative impacts. Grains grown with high levels of nitrogen fertilizers tend to be lower in zinc and higher in zinc-blocking phytates than grains grown with more modest nitrogen levels. With leaf vegetables, excess available soil nitrogen results in higher content of troubling nitrates and oxalic acid. Many leaf crops are exceptionally good at soaking up surplus ("luxury") nitrogen in the soil, leading to dangerously high nitrate levels in otherwise nutritious greens.

Proponents of synthetic nitrogen fertilizers generally claim that these drawbacks are relatively minor compared to their enormous benefit of doubling or tripling food production, and that without them perhaps another billion people would go hungry. It is a compelling argument and no one wants to pose somewhat abstract and largely future environmental problems

3 Rhizobia bacteria normally exist in a symbiotic relationship with legumes. Farmers and gardeners often increase nitrogen fixation by inoculating or coating their legume seeds with the type of rhizobia best suited to that legume. Rhizobia will persist for several years in the soil after a legume has grown there. However, nitrogen fixation is often improved 10–20% by inoculating the seed even if that legume has been grown in the soil recently. This is especially true in acid soils. A much smaller amount of nitrogen fixation is done by free soil bacteria (e.g. azotobacters). Nitrogen-fixing bacteria can also grow symbiotically with a number of non-legume species. Examples of these are alders (*Alnus spp.*), lichens, Casuarina, Myrica, liverworts, and Gunnera. These plants also account for much less nitrogen fixation than legumes.

4 In a scientific context 1 kilocalorie (kcal) = 1,000 calories. This is the amount of energy required to raise the temperature of 1 kg of water by 1° C. It is easy to get confused about calories and kilocalories because, in a nutritional context (what you'll find on food packages), the values given are actually for the number of kilocalories, but are referred to simply as calories. With food, calories and kilocalories are often used interchangeably.

against a hungry child. The problem is one of sustainability for the entire human race.

If our heavy dependence on industrial nitrogen fertilizer for food production cannot be sustained over a very long time, and most evidence suggests that it cannot be, then we need a transition strategy to move towards another way of growing food. It is a great challenge of our time to create a transition to sustainable agriculture quickly enough to minimize further ecological damage and with enough grace and compassion to not let children go hungry.

This will mean growing far more legumes to initially fix nitrogen from the air, and then carefully recycling that fixed nitrogen to gain maximum value from it. A key step in the transition toward sustainable agriculture is increasing the organic content in our food-producing soils. As organic matter decomposes, nitrogen is slowly converted to ammonium, which is absorbed by plant roots. Compared to the accelerated growth of crops grown with nitrogen fertilizer, this is slow food. Slow food can be grown for a much longer time than fast food.

***Phosphorus***

Phosphorus is a chemical element commonly found in inorganic phosphate rock. It is sometimes called "the bottleneck of life," because it is the factor that most limits the total amount of life—including bacteria, plants, and animals—on earth. Of all of the elements that are assembled to make living tissue the demand for phosphorus is greatest relative to its supply. Because of this it is often the availability of phosphorus that governs both the rate of growth of many organisms and the total biomass in an ecosystem.

Like nitrogen, phosphorus is essential to all known forms of life, playing a key role in the genetic template molecules DNA and RNA, and in the universal energy transport molecule, adenosine triphosphate (ATP). It is integral to the phospholipids that are main structural components of all cellular membranes. And for good measure it helps make bones stiff enough to support weight.

People get the phosphorus they need from food. Until recently this phosphorus all came to us from the slow breakdown of phosphate contained in rock in the soil, and the frugal recycling of phosphorus from organism to organism. The phosphorus in our food supply now comes increasingly from a handful of rock phosphate deposits that are mined and then synthesized into commercial fertilizer. Since the 1960s, our use of phosphorus fertilizer has risen nearly six-fold, from about 28 million tons to 160 million tons in 2008. Not only are we putting more phosphorus in the soil, but it is in a very ready-to-use, soluble form. The enormous expansion of global grain production during these decades would not have been possible without this huge increase in the use of mineral phosphorus fertilizer.

We are extracting phosphorus much faster than we are finding new deposits. Similar to crude oil, it requires ever more energy to recover ever poorer grades of phosphate. Planners expect that readily-available phosphorus for fertilizing crop fields will become seriously depleted within the next 50 to 100 years, when the human population is expected to peak.[5] The price of phosphorus fertilizer to farmers has already climbed sharply and may soon become a potent constraint to increased food production. Because nearly 90% of known phosphate reserves are in just four countries, control of this critical resource, for which no substitute exists, will likely soon become a global political headache.

There are other problems associated with our heavy dependence on mineral phosphorus for growing our food. The poorer grades of phosphate rock that we are now mining tend to contain high levels of cadmium. Cadmium is a cumulative toxin and carcinogen that is increasingly entering our bodies by way of food grown with phosphorus fertilizer.

This fertilizer is highly soluble, which makes it immediately available for plants. It also means that it can leach out or run off of soils and end up in our waterways. When this happens, the growth of algae and aquatic weeds, such as water hyacinth, is greatly stimulated. This over-fertilization of surface

5 Global Phosphorus Research Initiative www.phosphorusfutures.net

water is called eutrophication and leads to the rapid die-off of all fish and shellfish.

An additional problem is that plants grown with soluble phosphate fertilizers, as with soluble nitrogen fertilizer, contain higher levels of phytates. Phytates are phosphorus compounds that inhibit our ability to absorb iron, calcium, magnesium, and zinc. The prevalence and seriousness of iron and zinc deficiencies in developing countries make high phytate levels in grains a real problem.

If this sounds hopeless it doesn't need to be. Unlike petroleum and natural gas, which are destroyed when they are used, phosphorus can be recycled indefinitely. All natural ecosystems recycle phosphorus efficiently from organism to organism. Current agricultural and waste removal systems are washing phosphorus into the oceans where it can remain out of use for millions of years.

Like the rest of the world's living creatures, humans need to carefully recapture this nutrient and use it again and again. Hygienic and efficient systems for composting agricultural wastes, household food waste and humanure (safely composted human excrement), are already being rapidly developed; such systems return phosphorus to our food-growing soils. These composted soil amendments won't give the jolt of rapid growth that industrial fertilizer does. What they are able to do well is to feed the soil's complex food web of microbial organisms. That soil food web-especially bacteria, mycorrhizal fungi and earthworms-makes the existing phosphorus in the soil much more readily usable by plants. They also provide a relatively steady stream of phosphorus over a long period, rather than the quick spike from industrial phosphorus fertilizer. Slow and steady is another way of saying sustainable.

***Compost***

Compost is an all-purpose garden soil amendment that will improve the texture and fertility of any soil. Because most life forms have similar chemical compositions, well-rotted organic material, such as compost, usually contains all the required nutrients for plant growth in a relatively balanced form. In addition compost will make heavy clay soils looser and easier to work, and keep sandy soils from draining so quickly, helping both to hold more rainwater longer. It tempers the pH of soil, making acid soils less acidic and alkaline soils less alkaline. This makes the minerals in the soil more available for plant growth. Compost provides plants with a much longer-term supply of nutrients than chemical fertilizers.

To make a traditional compost pile, place layers of different types of organic material (manure, plant residues, vegetable scraps, chopped corn stalks, straw, leaves, peanut hulls, etc.) in a pile. Add enough water to make it moist but not wet. Turning the pile every two weeks or so will supply more air to the center and speed the process somewhat, though this is not necessary. When it is finished, compost will be black or dark brown, smell like soil, and you won't be able to recognize the original materials.

Vermicomposting, using worms to speed up the composting process, further improves the quality of the compost. As the organic material passes through the worm's intestinal tract the nutrients are rendered far more useful to plant roots. Compost can also be made by placing the organic materials in layers directly onto the garden soil, when it is not in use. This is called sheet composting.

Composting is an inherently forgiving process. When living beings die they are recycled into the raw materials for new living beings. Composting speeds the process along, but the recycling will take place anyway, so a relaxed attitude works well.

***Humanure***

Using simple compost technology to transform human waste into a safe and useful soil amendment, sometimes called humanure, is a practice that may soon be commonplace. While the idea of using human excrement and urine to help grow food is unpleasant in most cultures and unthinkable in some, there are two serious problems which humanure can at least partially address.

The first of these is that the world's nearly seven billion people generate a great deal of human waste every day, and there

is no simple way to dispose of it. Industrial societies generally rely on systems that flush wastes with purified water, pump it to large processing facilities, treat it with chlorine and other poisons to kill the pathogens, then treat the remaining sludge as toxic waste. It is an extremely expensive system to install and operate effectively. It involves the difficult task of separating the waste from the water so that the water can be made safe to drink again. Toxic by-products of the chlorination process, such as trihalomethane, frequently contaminate the recycled water.

In much of the world neither the money nor the water necessary to build and run modern US-type sewage systems is available. This is especially true in rural areas in the tropics. These tend to be the places where growers can't afford to buy nitrogen and phosphorus fertilizers for their cropland. Safely composting human waste to make agriculturally useful humanure could at least partially resolve both the problem of hygienic disposal of excrement and the problem of declining soil fertility in many communities.

There are a few key principals to keep in mind if you want to help develop safe humanure systems.

1. Study up. Human wastes are vectors for several infectious diseases caused by viral, bacterial, and protozoan pathogens, as well as parasitic worms, so the utmost caution is certainly justified in dealing with human waste. Learn the basics of composting and of infectious diseases. Study the work that has already been done in this field, especially the *Humanure Handbook* by Joseph Jenkins, and the World Health Organization Excreta Reuse Guidelines, both of which can be downloaded from the Internet for free.[6]
2. The simplest way to make sure pathogens don't survive is to compost with thermophilic (heat loving) bacteria, which generate temperatures high enough to kill the pathogens.
3. Build in a large margin of safety. Keep composting material from entering any waterways or rain run-off. Keep it out of the garden for at least one year to allow time for non-pathogen species to dominate. Grow crops that are harvested well above the ground level so that rain won't splash soil on them. Do not grow crops that are eaten raw, like lettuce or radishes, in humanure fertilized beds. Cook any food grown in humanure. Cooking provides a wide margin of safety.

If composting human wastes seems too daunting, you may want to start with recycling just the urine fraction. Fresh urine is nearly sterile. It contains 70–90% of the nitrogen excreted from the body, 45–80% of the phosphorus, and 60–95% of the potassium.[7] Using urine as a garden fertilizer will be more successful if a few guidelines are followed.

1. Collect urine in a container with a tight lid and distribute it daily to your garden, trees, or compost pile. Stale urine smells much worse than fresh because nitrogen is being lost to the air as ammonia. Plans to build composting toilets that separate out urine are available on the Internet.[8]
2. Dilute urine with at least five parts of water before applying it to plants. With very young plants a 10:1 dilution is better to reduce the risk of too much nitrogen. Put the urine on the soil, not directly on the plants.
3. Use urine fertilizer in combination with wood ashes, especially if your garden soil is acidic. The two waste products together can supply essential nitrogen, phosphorus, potassium, calcium, and magnesium to your garden. Research in Finland has shown the combination of urine and wood ashes to be comparable to expensive commercial fertilizer in stimulating plant growth.[9]

6 www.jenkinspublishing.com/humanure.html and http://whqlibdoc.who.int/publications/2006/9241546859_eng.pdf

7 Milne, Robert (2010) *Organic Vegetable Growing: A Practical, Authoritative Guide to Producing Nutritious and Flavourful Vegetables from Your Garden or Allotment,* Spring Hill ISBN: 9781905862382 p. 105

8 ecovita.net/news/wp-content/uploads/2009/07/PrivyKit-Baja-Box-Directions.pdf

9 Surendra K. Pradhan (Dept. of Environmental Science, University of Kuopio, P.O. Box 1627,

4. Wait at least thirty days to harvest vegetables after they have been fertilized with urine, and cook them at least briefly to add a further margin of safety.
5. Another approach is to use urine to accelerate the decomposition in your compost pile, and then use the finished compost to fertilize your garden soil.

Ultimately, creating sustainable food systems will require us to learn how to recycle all the nutrients that we use, including our bodily wastes. Our rapidly growing knowledge of biology will help ease the transition away from simplistic and damaging ideas about waste disposal.

## COVER CROPS (GREEN MANURE)

Cover crops, or green manure crops, are plants grown mainly to improve the soil rather than to provide food. They are especially important anywhere that gardeners don't have access to enough organic matter to make sufficient compost. Sometimes the soil is so degraded and devoid of nutrients that it won't produce a cover crop. In these situations it may be necessary to apply enough manure, compost, or chemical fertilizers to set crop growth in motion. As cover crops starts producing more biomass it will become possible to begin building up the soil organic matter and fertility for the long term. Most soils are 1–6% organic matter. Some organic gardens and crop land may contain as much as 10% organic matter, while conventional crop land is usually closer to 1%. The higher level of organic matter has many agricultural and environmental benefits.

There are several types of plants that make suitable cover crops. Plants of the legume (pea) family, such as beans, pigeon peas, alfalfa, and clover are grown primarily for their ability to add valuable nitrogen in a useful form to the soil. Plants of the grass family, such as barley, wheat, and rye, produce large amounts of organic matter. Their dense mats of roots create networks of tiny channels for air and water to move within the soil. Plants with strong central taproots, like turnips, can punch holes into heavy subsoil, allowing for better drainage. Some cover crop plants, such as mustard and buckwheat, can accumulate phosphorus, zinc, potassium, copper, and other essential minerals from deep in the subsoil and make them available for crops that follow.

Cover crops can be planted in any unused garden beds or fields. They can be also be grown before a heat-loving crop, such as tomatoes or eggplant; or after an early crop, like potatoes or spinach. Often, a cold hardy cover crop, such as bell beans, Austrian winter peas, barley, or turnips, can be planted after the summer garden has finished producing, and be turned under before warm weather crops get planted in late spring. In this way the cover crops protect the garden soil from erosion all winter and add fertility without interfering with garden produce.

Another alternative way to use cover crops is with intercropping. This is the practice of planting two crops in the same field at the same time for their mutual benefit. Typically intercrops will produce about 30% more than when the two crops are grown separately in the same area. The classic example of this is corn intercropped with beans and squash. This intercrop, referred to as "three sisters," added stability and productivity to many Native American agricultural systems. Low-growing cover crops, such as clover, can also be undersown with corn, broccoli, okra, and other taller plants. The timing and seeding rate of undersown cover crops needs to be adjusted so that competition with the primary crop is minimized.

Generally cover crops are cut down near the ground level when they begin flowering. This is the stage of the plant growth when they will add the most to your soil's fertility. They can be cut with a scythe, a swing blade, a string weed cutter, a lawnmower or even a very sharp hoe. The cover crop can then be incorporated into the top few inches of the garden soil with a hoe or rototiller. It is usually best to wait at least

FI-70211 Kuopio, Finland), Jarmo K. Holopainen, Janne Weisell, and Helvi Heinonen-Tanski, "Human Urine and Wood Ash as Plant Nutrients for Beet *(Beta vulgaris)* Cultivation: Impacts on Yield Quality," Journal of Agricultural and Food Chemistry 58(3), February 10, 2010, 2034-2039. (American Chemical Society, 1155 16th St., N.W., Washington, DC 20036)

**CHART 11–1**
**LIFE IN GOOD GARDEN SOIL***

| | *One Acre* | *One Hectare* |
|---|---|---|
| **Mammals** | 2 lb | 2.2 kg |
| **Protozoa** | 133 lb | 150 kg |
| **Earthworms** | 900 lb | 1000 kg |
| **Insects** | 900 lb | 1000 kg |
| **Algae** | 900 lb | 1000 kg |
| **Bacteria** | 2000 lb | 2200 kg |
| **Fungi** | 2400 lb | 2600 kg |

**Teaming with Microbes: The Organic Gardener's Guide to the Soil Food Web, Revised Edition*, by Jeff Lowenfels and Wayne Lewis page 28, Timber Press 2006, ISBN-13: 978-0-88192-777-1

three weeks before planting the next crop so the soil biochemistry has time to settle down.

An increasingly popular technique is to simply leave the cut cover crop lying on top of the soil as mulch. Once it has wilted a bit seedlings can be planted in holes punched through this mulch. This works much better with plant sets that are large enough for their leaves to extend above the mulch layer, than with very small seedlings. It is not well suited for direct seed planting of most crops.

Yet another system for improving soil with cover crops involves setting aside an area roughly equivalent to the size of your vegetable garden and using it exclusively to provide fertility for that garden. Cover crops are grown in this patch and cut just before flowering. The crop is then removed from this patch and used to make compost or mulch for the garden. Generally, mixes of cover crops almost always include a legume, a grass and sometimes a member of the mustard family.

If the land is already rich in nitrogen, legumes will use the existing soil nitrogen rather than fix it from the air. In fact, a high level of soil nitrates is considered the biggest single obstacle to satisfactory nitrogen fixation from legume cover crops. Removing the leguminous cover crop, and hauling it to a nearby garden or compost pile prevents the soil nitrogen level from building up and allows efficient nitrogen fixing to continue for several crops.

The cover crops can capture carbon and nitrogen from the air indefinitely, increasing the fertility and organic matter content of your vegetable garden. Other nutrients, especially phosphorus, potassium, calcium, and magnesium, will eventually become deficient if you keep removing cover crops, so these nutrients need to be replaced in the fertility patch. Switching the garden and cover crop patch every few years is a good idea for long term productivity. This interrupts the life cycle of many soil disease organisms and reduces the likelihood of soil micronutrient deficiencies. This same system can be employed on a smaller scale by using alternating sections of your garden for vegetables and for growing cover crops to support that vegetable production.

An especially useful but rarely used technique is harvesting part of the cover crop to use as leafy vegetables. This involves growing cover crops with edible leaves, such as cowpeas, beans, barley, wheat, mustard, and turnips, and harvesting part of the leaf crop for food while using the bulk of it to improve the soil. Edible cover crops are the subject of Chapter 12.

## PLANTING LEAF CROPS

Improving the structure and fertility of the soil is an ongoing process that gets progressively easier but is never completed. Once you are satisfied that your soil will support

a healthy crop, it is time to start planting leaf crops. Planting everything during one weekend after the weather turns warm and then thinking the garden is planted is really folly. All serious gardening cultures and traditions, such as in Southeast Asia, use a more complex pattern of sequential planting that optimizes the growth of the individual crops and takes advantage of the entire growing season.

***Direct Seeding***

Plants with edible leaves can be started from direct seeding, from transplants or from vegetative reproduction. Direct seeding is the most common method, and adhering to a few principles will improve the odds of growing healthy plants from the seeds you plant. The biggest cause of poor germination is planting seed too deeply. For most seeds a depth roughly twice the diameter or length of the seed is optimal for planting. When the soil is already warm, as when starting fall plants in August or September (in the northern hemisphere), the planting depth can be doubled so the germinating seed does not dry out. Firming, but not tamping, the soil around newly planted seeds will ensure good contact with moist soil. This can be done with your hands or with a plank. Most seeds like to germinate in the dark. Lettuce seed is an exception and can be planted on the surface. It is especially important to press lettuce into contact with the earth.

Seed can be thought of as a living plant in a state of suspended animation. Planting seed that has been saved from the previous year's crop is an important traditional agricultural activity and a means of producing more food for less expense. There are several good books and guidelines from the Internet to help you get started with seed saving. Be aware that seed saved in humid climates is somewhat more prone to transmitting viruses. This is why commercial seeds are usually grown in semi-arid locations. Also remember that F1 hybrid seeds will not reproduce plants with the same traits as their parents.

Leaf crops are typically planted more densely than crops for seeds, fruits, or tubers. Often the same plant, cowpea for example, can be grown either for its seeds or for its leaves. When growing multi-use crops the planting density can be adjusted according to what part of the plant is the most important output. When grown for leaves the plants are usually grown at least twice as densely, so much more seed is needed to sow a given area.

To give an extreme example, moringa is grown for its pods and seeds, as well as for its edible leaves. When grown for pods or seeds the recommended spacing between plants is about 3–5 m (10–15 ft) apart. When grown for maximum leaf yield the spacing is more like 15–50 cm (6–20 in) apart. This means in a typical 9 sq m (100 sq ft) home garden bed you might plant 3 moringa seeds for pod production, or 36 to 400 seeds for maximum leaf yield. The leaf yields from the highest density planting can be dramatic. Tests in Nicaragua yielded 640 metric tons per hectare (290 tons/acre) of fresh green matter (leaf with some stem). Although botanically identical to moringa grown for pods, from an agricultural perspective, moringa grown for leaf is a very different crop.

This type of extremely high leaf yield requires heavily fertilized soil, irrigation, and, of course, plenty of available seed. While there are definitely benefits to sharply increasing planting density for many leaf crops, for most home growers some compromise between maximum yield and reduced cost of inputs is optimal. Cost and availability of seed is an important restraint for home growers. Typically, vegetable seed is purchased in very small packets at ever-climbing retail prices from local stores or from seed catalogs. Seed packets that cost upwards of $3.00 don't encourage high-density planting or experimenting with new crops.

***Transplants***

However they obtain their seeds, many gardeners stretch how far they go by planting first in little containers and transplanting them into the garden only after they have become small but healthy plants. This is a good strategy for garden planting but usually not practical for cover crops. Because they are started in potting

soil that is very light and porous they quickly develop vigorous root systems. Conventional potting soil is based on peat moss combined with perlite and vermiculite, two inert volcanic minerals. Unfortunately peat moss is being mined at an unsustainable rate, and the two minerals are heated with a great deal of energy to expand them like popcorn. More ecologically sound and nearly as good potting soil can be made by combining two- or three-year-old rotted leaves or compost that has been sifted through quarter-inch hardware cloth with course sand. Most experts recommend sterilizing the mixture with heat to eliminate plant pathogens.

Growing transplants gives the gardener several benefits. The most important of these is being able to extend the growing season. This usually involves starting transplants in a special structure, such as a greenhouse or a cold frame, that modifies the growing climate. Heat loving plants can be started several weeks earlier than they could be safely planted outdoors. This effectively lengthens the growing season, often by enough to enable gardeners to successfully grow tropical and semi-tropical leaf crops where they would otherwise fail.

Another important function of transplants is to allow more accurate spacing of plants. Hard rains, birds, mice, insects, and fungal infections are common factors that reduce germination of garden seed. No matter how carefully one plants, seeds germinate sporadically, leaving overly thick patches that need to be thinned and bare patches that need to be replanted. Because transplants are already successful plants that have survived their most vulnerable period they tend to grow well in gardens. They can be set out in the garden beds at an optimal spacing without wasting seed. Transplants also allow the gardener to replace plants that get eaten by pests or fail to thrive for whatever reason. This makes for the best use of the valuable space in the garden beds.

It helps to "harden off" the seedlings by putting them in a spot outside but protected from the wind during the day for a couple of days to get them acclimatized to the harsher climate of the garden. When setting out transplants turn the plant upside down to get it loose from the container. If you handle the plants, grasp them by the leaves but not by the stem. They can grow new leaves but if the stem is damaged the plant won't fully recover. Some roots on the young plants are always damaged in the transfer to the garden and the plants are very vulnerable for about three days until new rootlets can take hold. This transplant shock is minimized by watering the plants well and shading them for three days.

***Vegetative Reproduction***

Some leaf crops, especially tropicals, are not normally reproduced by seed. For example, chaya, cassava, and katuk are almost always planted from stem cuttings. These are generally pieces of actively growing stem, 15–30 cm (6–12 in) long. The stem cutting should include several internodes. These are the places where the new branches form. Stems should be cut with a sharp knife or snips and the wound kept dry until it is planted. Stem cuttings are normally planted with about half their length underground. Trim off all the leaves with clean cuts. Make sure the end that was pointing up on the original plant is still pointing up on the new one. In shallow soil stem cuttings are sometimes planted at a slant.

Sweet potatoes, whether grown for the starchy roots or the leaves, originate with slips. Slips are miniature plants that sprout from the tuber. Some crops, such as moringa or vine spinach, can be started from either seed or stem cuttings; though it is generally thought that stronger plants emerge from seeds than cuttings. Many herbs, such as mint, rosemary, and thyme, can be easily reproduced by snipping off a section of stem about 13 cm (5 in) long, then stripping the leaves and branchlets off the lower half of that stem, and planting it in moist soil up to the first remaining leaves. Tropical beans can often be reproduced from a section of root if some stem is included.

Some woody plants that are more difficult to reproduce from stem cuttings can be encouraged to do so by dipping the cut end of the stem in a powder containing rooting hormone (often sold commercially as

Root-Tone or Clonex). This signals the plant cells to make more roots instead of leaves and branches. This may be helpful with chaya, katuk, cassava, or other partially woody species, especially if older, more mature stems are used.

***Volunteers***

Volunteers are civic minded people who work without pay. On normal days they take meals to old folks, catalog library books, and clean up the crap others toss out along our roads. On bad days they fill sandbags, put out forest fires, and pull motorists from snowdrifts.

A volunteer is also the name for a garden plant that no one planted. It volunteers to grow where it will, usually from self-sown or accidentally dropped seed. It is almost a weed—except that someone wanted it sometime in the past. Some garden crops produce plentiful seed and drop it around the parent plant. Some plants that are prone to volunteering in vegetable gardens are excellent leaf crops.

Almost without fail I get plenty of free sets from vine spinach *(Basella rubra)*, quail grass *(Celosia argentea)*, red Hopi amaranth, *(Amaranthus cruentus)*, spider wisp *(Cleome gyandra)*, purslane *(Portulaca oleracae)*, orach *(Atriplex hortensis)*, shiso *(Perilla fructans)*, rice beans *(Vigna umbellata)*, hyacinth beans *(Lablab purpureus)* and others every spring. In addition to avoiding the cost of buying new seed, the volunteers have a couple of advantages over planted seeds. They know when to sprout. Unlike human gardeners, they are rarely too impatient to wait until the soil temperature is adequate, or too busy or forgetful to plant till optimal conditions have passed. Volunteers have also gone through at least one round of Darwinian selection. They are the offspring of plants that grew well enough to bear viable seed in the actual conditions of your garden. Sometimes new localized varieties of edible plants can arise through your tolerance, observation, and choosing of the best candidates.

Because volunteers often sprout in profusion, I am able to further select the most vigorous individuals to grow. I transplant the strongest among them to achieve a desirable spacing. The others I let grow until they begin to interfere with other plantings, then I cut the leafy tops and either eat them or dry them for later use. Some of them-notably vine spinach, amaranth, and soko-can be harvested in this way two or three times, supplying me with a large quantity of high quality organic greens with no cost or effort other than the harvest. When they begin impinging on other crops I slice them off at the ground level with a sharpened stirrup hoe. It doesn't seem fair, but the potent reproductive capacity of these plants doesn't allow for very many to reach maturity and have families of their own.

The edges of compost piles are often a good source of volunteers. Fruiting plants such as tomatoes and squashes will come up that are often crosses bearing poor quality fruit, but in the case of the squashes they generally have good quality edible leaves. Tomato and potato leaves aren't quite edible. At the end of the growing season, we will go through our leftover garden seed and separate out seeds that may be good for next year's garden. The rest we mix together and toss into the compost. This almost always results in some cabbage family greens (cabbage, broccoli, kale, collards, mustard, turnip, radish, etc.) at the edge of the compost pile at the first sign of warming spring weather. These can be transplanted or simply pinched off and added to salads.

There is, alas, some downsides to garden volunteers. First of all, they don't usually transplant as nicely as seedlings started in fluffy potting soil, and it is easy to damage their roots transplanting them from heavier garden soil.

Secondly, they can become weeds. The line between weed and not weed is not always crisp. Sometimes I've had my fill of amaranth, for example, and they just keep sprouting up everywhere in my garden. The earliest volunteers are the least intrusive as they are less likely to be competing with other plants that I am trying to grow. Generally, annual vegetables don't become noxious weeds but there are certainly examples of cultivated plants escaping and becoming weeds. This is more of a problem

in the tropics where harsh winters don't knock back vegetation.

Several plants that are sometimes grown for edible leaves have in fact become invasive in other locations. Water spinach *(Ipomoea aquatica)*, ivy gourd *(Coccinia grandis)* and oyster nut *(Telfairia pedata)* come to mind. If volunteers are allowed to play in the garden, it is important for the gardener to assume responsibility for not letting them become pest plants. With annuals this is a matter of cutting the plants before they have time to bear seeds.

Not everyone likes working with volunteers. The level of control is too low for most fastidious gardeners, and they can give an early garden a wild and unkempt look. For me they are part of the magic of gardening: the garden expressing itself and remembering its past. I enjoy surprises and I have not completely given up on the idea of a free lunch.

***Weeds***

Weeds are basically just plants growing where you don't want them to grow. Many of the most common weeds of gardens, fields, and lawns have edible and nutritious leaves. Some are prized as spring greens, rich enough in vitamins and minerals to kickstart our bodies after months of the bland stored foods of winter. Some, like purslane and dandelion, are even sold in regional markets.

Many garden weeds are pioneer plants. These are plants whose ecological role is to quickly reestablish a cover on soil disturbed by flood or fire. They are opportunistic plants that grow quickly and produce a large quantity of seed in a short time. After a flood or a fire these are the first plants to grow on the disturbed land. Many weeds, such as lambsquarters and pigweed, can barely survive in well established ecosystems like forests or prairies. They prefer to colonize disturbed ground. Because human activities like gardening, farming, and construction create far more disturbed land than natural events, most weeds are anthropophilic, or human loving, species. So are cockroaches, cows, dogs, and cold viruses. Anthropophilic species are those whose population thrives in association with human activity.

Controlling weeds is among the most time consuming of gardening tasks. Often eating them is a reasonable strategy. Fortunately the garden is an ideal place to harvest weed leaves. The soil is ideally rich and not contaminated. Additionally, all weeds eaten as greens are much better tasting as well as better textured before they flower. This works out well for weed control because it means that the young plants are eaten before they can reproduce, creating more weeds. If you start running short of weeds to eat, just take a nap and they will be back.

There are dozens of weeds with edible leaves. Here are some of the best, from my experience.

***Pigweed*** - There are several plants that are sometimes called pigweed. The most important are probably red root amaranth *(Amaranthus retroflexus)*, spiny amaranth *(Amaranthus retroflexus espinosa)* and Palmer amaranth *(Amaranthus palmeri)*. In the same family as the ornamentals love-lies-bleeding and Joseph's coat, pigweed is one of the most universal and one of the most nutritious weeds. It is best when quite young, and it should be cooked. Spiny amaranth requires more caution harvesting because of the little thorns.

***Lambsquarters*** - *(Chenopodium album)*. This is another very common weed found in rich soil around barns and compost heaps, and in gardens and farm fields. It is in the same family as spinach, beets, and Swiss chard. It is rich in iron, calcium, and protein, but like spinach, contains high levels of oxalic acid. It should be avoided by people with a history of kidney stones. Lambsquarters can be eaten raw when very young, but should be cooked briefly otherwise.

***Dandelion*** - *(Taraxacum officiale)* Perhaps the best known of all weeds, dandelion has been used as a spring tonic vegetable and to make dandelion wine for centuries. The leaves need to be eaten before the flower forms or they can be extremely bitter. This is a challenge because often we are only aware of the dandelion's presence after we see the distinctive bright yellow flower. Although people go to great lengths

to exterminate them from lawns, dandelion greens are rich in beta-carotene and vitamin C, and make a good addition to the diet.

***Stinging nettles*** - *(Urtica dioica)* Famous for its sting, this plant thrives in rich damp conditions, such as along creek banks. When one makes contact with this plant it defends itself by releasing formic acid and enzymes from tiny tubes (trichomes) along its stem and leaves, into the skin of the intruder. Nettles need an expensive investment in defense because they are among the most nutritious of all plants, sought after for their rich content of protein, iron, calcium, and vitamins. Care and gloves should be used when harvesting stinging nettles, but after it has been dried or cooked it stings no more and becomes a well-behaved pot herb.

Another plant sometimes called stinging nettle is a subtropical member of the Euphorbia family and a close relative of chaya *(Cnidoculus acontifolius)*. Its botanical name is *Cnidoculus stimulosus* and it is also aptly called "tread softly," as it is protected by trichomes more painful and enduring than the unrelated northern stinging nettle.

***Purslane*** - *(Portulaca oleracae)* This plant is sometimes cultivated, especially a larger-leafed, golden colored variety, but is most often encountered as a garden weed. It can grow most anywhere, even out of a gravel driveway. It has a low sprawling habit and reddish succulent stems with small jade colored leaves. It is one of the few weeds that can be eaten raw even when fully grown. It has a tart flavor that goes well with salads. It becomes slightly mucilaginous when cooked and is sometimes used to thicken soups. Purslane has attracted some interest lately due to its relatively high content of alpha-linolenic acid, an omega-3 oil.

***Dock*** - *(Rumex)* There are several edible weeds in this family, including curly dock, yellow dock and sheep's sorrel. They are very common weeds in fields and at the edge of gardens. The large drooping leaves are best eaten when young, and even then can be a bit tough and chewy. Drying the leaves and grinding them to a fine powder is a technique that allows them to be eaten until they begin flowering.

***Plantain*** - *(Plantago major)* Plantain is an easily recognized and very common weed with wide, tough parallel-veined leaves and a wiry vertical flower stem. Except when very young the leaves are tough to chew. However, plantain leaves don't get bitter as they grow so it too is an excellent candidate for drying and grinding.

***Chickweed*** - *(Stellaria media)* This is a common garden weed, forming a carpet of foliage in moist rich soil. It is especially useful as an edible weed because it is available all winter long in much of the temperate zone. It can be eaten raw in

Plantain *(Plantago major)*

salads or on sandwiches, but its stems are a bit stringy so it is best cut into small pieces. It is another nutritious, edible weed that can be easily dried for later use.

***A Few Cautions***

- Don't eat a weed unless you are sure what it is and know that it is edible. Eat only the edible part of the plant. Err on the side of caution, as some parts of some weeds are toxic.
- Don't eat large amounts of any one weed at one time. This is a reasonable general precaution that offers protection against possible toxins, contamination, or allergens.
- Cooking is essential for many weed greens.
- Avoid eating weeds from the following locations:
    - Heavily trafficked roadways
    - Around the base of older buildings where lead paint scrapings may be lurking
    - Where there has been heavy use of herbicides or fertilizers, i.e. golf courses
    - Where there is likely to be a concentration of pet feces

## CARE OF LEAF CROPS

***Supplying Water***

After sunlight, water is the most important thing in the life of your plants. Most plants are over 80% water. Most leaf crops need about 2.5 cm (1 in) of rain per week for rapid healthy growth. When it is very hot and dry, more than that is needed, and less is needed when it is cool and cloudy. You can compensate for rainfall shortages by watering deeply once a week. Young plants with shallow roots may benefit from more frequent watering, but shallow irrigation doesn't encourage the growth of strong deep roots.

Watering in the late afternoon is usually the most efficient because less moisture evaporates overnight than in the hot sun of daytime. When watering is delayed until evening the risk of plant disease increases, especially if the leaves remain wet overnight. Adding water below the soil surface also results in less water lost to evaporation. This is sometimes called root zone irrigation. There are a number of techniques for getting water to the plants' root zone, including porous soaker hoses and drip irrigation systems. A simple, small scale variation on drip irrigation is the Chapin system. This uses a five gallon plastic bucket hanging 120–150 cm (4–5 ft) off the ground, from a post or other support. The water slowly gravity feeds into thin gauge plastic tubing with emitter holes near the plant roots. A larger system uses a 55 gallon drum on a raised platform to gravity feed water to a larger area. Any irrigation system that uses soaker hoses, microtubes or emitter holes needs to use water that contains very little sediment or it will quickly clog.

An even simpler method of root zone watering involves sinking an unglazed clay pot or a bucket with holes punched in the bottom into the ground, so that only the rim is above ground. The pot or bucket, which is set in the ground before planting, is filled with water that slowly seeps out into the root zone.

Another simple root zone irrigation technique relies on capillary action moving water through a wick made of discarded cloth of some sort. This system works especially well with shallow rooted plants that require a reliable supply of water. A blanket or other similar cloth is laid in a trench 15–25 cm (6–10 in) deep then covered with garden soil. Plants are spaced above or just to the side of the wick. One end of the wick cloth stays in a bucket of water that is sunken so that just an inch or two remains above the ground level. As the root zone dries out, water is wicked to it along the buried cloth, providing a steady supply of water to the plant roots while minimizing evaporation losses. Synthetic materials break down much more slowly that natural fiber cloth.

Any irrigation method is made more effective by using a protective layer of mulch around the plants. Mulch is usually compost, straw, leaves, newspaper, cardboard, or other organic material. It keeps the soil cool, reduces evaporation and

keeps weeds from sprouting in the garden. Weeds compete for water resources with your plants. Sand is another interesting mulching material. Plastic sheeting is sometime used as mulch as well with holes sliced into it for the plants. It is very good at retaining soil moisture but has a number of unresolved economic, environmental, and aesthetic issues.

***Controlling Unwanted Weeds***

Weeds are plants that are growing where you don't want them to be growing. Dealing with weeds is often considered the most onerous part of vegetable gardening. In addition to soaking up water intended for your crops, weeds compete with your garden plants for sunlight and soil nutrients. Some of the weeds that have become naturalized and common throughout much of the world are also edible and nutritious greens. These include dandelion, pigweed (amaranth), lambsquarters, purslane, dock, plantain, and chickweed. These can be picked and eaten when young, turning enemies into friends, or at least snacks.

In addition to mulching and eating, a good way to deal with weeds is to cut them off just below the soil surface with a hoe. It is easier and faster to frequently go through the garden slicing the weeds off at the ground when they are very young, than to wait until they are bigger and well rooted. A hoe with a long handle and a razor sharp blade makes this process relatively fast and painless. Cutting any nearby weeds down before they form seeds will reduce the next crop of weeds. Medieval agriculturalists expressed the logic of this strategy as "One year to seed, nine years to weed."

Chemical herbicides are rarely necessary or appropriate for controlling weeds in small scale leaf growing operations. Where perennial grasses, nutsedge, or other persistent weeds are a problem, you might try smothering them with cover crops until they are weakened. Densely planted cover crops such as velvet beans will prevent the weeds from getting enough sunlight and eventually they will die out. It is not an instantaneous solution.

While velvet beans are an excellent cover crop and an excellent smother crop, their leaves cannot be eaten by humans. There are, however, several good smother crops that have edible leaves, including hyacinth beans, cowpeas, and sweet potato vines. While they may not be quite as effective at smothering your weeds as velvet beans are, their ability to simultaneously produce edible greens may make them a better choice.

Another technique for deterring persistent weeds is called "solarizing." It is useful only for relatively small patches. The soil is tilled or plowed then wetted, then covered with a thin (2 mil) black plastic sheet for 2 to 3 weeks. This should be done in mid summer so the soil temperature will rise quickly to kill most grasses. Deep rooted perennial weeds might not be completely killed but should be sufficiently weakened to be more easily controlled. Most of the troublesome grubs, weed seeds, nematodes, and pythium fungi (the organisms that cause damping off) under the plastic will also be killed.

***Controlling Insect and Animal Pests***

Almost all plants that humans grow in order to eat are attractive food for some insects and animals, and leaf crops are no exception. The portion of the total global food harvest that ends up feeding insects and animals has been estimated to be as high as one-third. It is essentially impossible to prevent all insect damage to your leaf crops, but fortunately there are sound strategies to limit damage to acceptable levels.

The best approach to the problem is often called Integrated Pest Management. This means using a mix of different techniques starting with the least intrusive, and going to stronger interventions until the problem is down to an acceptable level. These techniques, roughly in the order they should be used, include the following:

- Maintain good fertility and good structure in your garden soil with ample organic matter. Remember that healthy plants growing in healthy soil are more able to withstand insect attacks.
- Graciously accept some loss and some cosmetic damage as unavoidable.

- Grow a complex mixture of plants, including aromatic herbs and flowers, to confuse the chemical sensing ability that most insects use to locate their targets.
- Time your planting schedule to avoid peak insect activity.
- Create some habitat for animals such as birds, lizards, frogs, turtles, bats, and toads, which eat harmful insects. Small ponds, birdhouses, trellises, and perches attract bluebirds and other birds that happily eat moths, caterpillars, slugs, and other pests. Make a couple of toad houses from small clay pots turned upside down with an opening chipped into one side.
- Plant decoy or trap crops. For example, rabbits will prefer eating a trap crop of clover to your beans. Several insect pests that attack broccoli, cabbage, and cauliflower will be drawn instead to a nearby crop of mustard.
- Use physical barriers such as screen, mesh, or fencing to separate pests from your crop. Relatively inexpensive polypropylene cloth, sometimes called floating row covers, can be laid directly on the crops or stretched over a frame. It makes an especially good barrier because it allows penetration of most of the sunlight and water but excludes even very small insects like flea beetles from eating your crops. Remay and Agribon are two popular brands available from farm stores and catalogs.
- Handpick insects. Early morning is usually when most insects are the slowest and easiest to catch. Many insect pests, including Japanese beetles and harlequin bugs, have a defense mechanism of dropping from the plant they are eating at the first sign of danger. Lightly shaking plants is enough to convince them to drop into a container of water that you are holding below them. A couple of drops of detergent in the water will make it impossible for them to escape. Feed the Japanese beetles to your chickens; eat them later as scrambled eggs.
- Make repellents by blending, then steeping any combination of the following ingredients in water: garlic, onion, marigolds, chili peppers, tobacco, pennyroyal, mint, or tansy. After they have soaked for 24 hours, strain out any solids and spray on affected crops. Add a drop of soap to help the repellent stick to the leaf surface. The strong smells and flavors will confuse or discourage many insects and animals, and reduce feeding. You will need to re-spray after rain or overhead watering.
- Use natural insecticides such as neem, Bt *(Bacillus thuringiensis)*, rotenone, or pyrethrums. Try to wait at least a week after applying, and wash food well before eating after using any repellents or insecticides, even natural ones.
- Avoid powerful synthetic pesticides. They are prone to kill non-target insects and can disrupt the natural balance of the garden environment in unexpected ways. For example, they may alter the reproductive chemistry of important crop pollinators or kill off beneficial ladybugs that are controlling the aphid population. Ultimately it is almost always better to plant a bit more in order to make up for moderate insect damage than to expose your family to agricultural poisons in their food.

(See “Eating Pests” on page 132.)

***Controlling Plant Diseases***

Not unlike humans, living plants are subject to diseases caused by infections from various bacteria, viruses, and fungi. There is very little in the way of antibiotics for plants, so it is essential to focus on prevention rather than cure. Prevention is mainly common sense and hygiene. Strategies for reducing plant disease include the following:

- Don’t plant seed that appears moldy.
- Remove diseased plant material from your garden and don’t use it for compost. It is unlikely that your compost pile will reach a temperature high enough to kill all the fungal spores and viruses.

- Use compost, organic mulches and cover crops freely. A garden soil that has a vigorous microbial life has many checks and balances to reduce the likelihood of serious disease outbreaks.
- When you clean out plant containers at the end of a growing season, wash the inside with a 10% solution of liquid chlorine laundry bleach.
- Make sure plant spacing allows for some air movement. This is especially important in hot humid zones or areas with little wind. This seems to contradict the dense planting strategy so an optimal compromise must be found. Fortunately, leaf crops seem less prone to disease than fruiting crops.
- Rotate your crops so that members of the same plant family don't follow each other in the same garden spots. Some disease organisms slowly build populations in the soil if the target plant is present year after year. Crop rotation interrupts this buildup.
- If your crops show signs of fungal or virus disease, you can try drenching them with a tea made from nettle leaf or horsetail, or an actively aerated compost tea.[10]

Cranberry Hibiscus *(Hibiscus acetosella)*

10 *Teaming with Microbes: The Organic Gardener's Guide to the Soil Food Web, Revised Edition* by Jeff Lowenfels and Wayne Lewis, Timber Press; Revised edition (February 24, 2010), ISBN-10: 1604691131, ISBN-13: 978-1604691139

## EATING PESTS

From an ecological agricultural viewpoint, eating the insects that are eating our crops offers a long term strategy for controlling their populations, without the toxic cycle of pesticides and increasing genetic resistance to those pesticides. There are many cultures that view insects as a source of food. Entomophagy, the eating of insects, is still practiced in much of the tropics, especially in rural areas, and it is estimated that at least 1,500 different insect species are routinely eaten.

There is growing interest in raising insects for food, because it can be done with very little space and very little start-up capital. Like fish, insects are not warm-blooded so they don't require food simply to keep their bodies warm. As a result, they are far more efficient at converting feeds to protein than beef, pigs, or chickens. As the price of animal feed rises, the ecological advantage of raising insects will likely become more obvious.

Systems for efficiently harvesting edible insects from crops would need to be developed, but the synergistic benefits of reduced crop damage and an additional source of food, may be a significant resource for poor gardeners and subsistence farmers. Most insects that are eaten are rich in protein and essential fatty acids. What may be more important is that many edible insects are excellent sources of zinc and iron. Zinc and iron deficiencies are widespread public health problems. A low cost source of dietary zinc is especially significant because plants, including leaf vegetables, are poor sources of zinc, and animal-based foods are too expensive for many families.

There are some cautions. Not all insects are edible. Some have defenses to fend off predators that are toxic to us. It is also important to avoid collecting insects to eat in areas where they may have been exposed to high levels of pesticide. This is already an issue with honey bees and indiscriminate pesticide use. There is also some possibility that people who are allergic to shrimp or crab may be allergic to some insects, because they are very similar creatures.

There are some dangers and drawbacks to any source of food. Being well informed is almost always the best protection. For adventurous gardeners looking for new ways to defend their crops, there are several books and websites and even a magazine devoted to eating insects. In the struggle against hidden hunger, leaf vegetables and edible insects together could become a formidable force: a dynamic duo of low cost micro-nutrients.

*Insects As Food: Why the Western Attitude Is Important*
Gene R. DeFoliart
Annual Review of Entomology, January 1999, Vol. 44, Pages 21–50 (doi: 10.1146/annurev.ento.44.1.21)

*Man Eating Bugs: The Art and Science of Eating Insects*
Peter Menzel and Faith D'Aluisio
Material World (March 1, 2004)
ISBN-10: 1580080510
ISBN-13: 978-1580080514

*Creepy Crawly Cuisine: The Gourmet Guide to Edible Insects*
Julieta Ramos-Elorduy February 1, 1998
Park Street Press, Rochester, VT USA
ISBN-10: 089281747X
ISBN-13: 978-0892817474

## LEAF HARVEST

You have chosen a site, laid out the garden beds, improved the soil, made sure your plants weren't thirsty, and overcame or outlasted the weeds, pests, and diseases. While most vegetable gardeners will find some deep pleasure in the work that leads to the harvest, the harvest itself is the pay-off time. Harvesting green leaf crops is easy but there is still one important concept to grasp and a few simple tips.

### *The concept: pruning the lead stem*

Many plants exhibit apical dominance. They have a lead stem that grows skyward making the plant taller. When the lead stem is cut bio-chemical messengers inform the plant to create new side branches. You may have seen this effect in the regrowth pattern of some trees cut back to keep them out of power lines.

The ideal system for raising leaf crops takes advantage of this pattern of pruning and encouraging new branches. Crops that lend themselves to this are sometimes called cut-and-come-again crops. The main advantage of these crops over plants like head lettuce, where the entire plant is harvested then replanted from seed, is that the living root system and the stem remain in place. This means that the plant can immediately put its resources into producing new edible leaves rather beginning anew building fibrous root and stem tissue. For plants as varied as quail grass, basil, and moringa, repeated pruning of the lead stems can result in the production of many times more edible leaf per plant.

The benefits of this approach go well beyond the large increases in yield. Soil erosion is greatly diminished by leaving the plant's root system and part of its above-ground structure intact rather than removing the whole plant. Pruning allows the grower to maintain the size and shape of the plant in a way that makes for easy harvesting and allows undersown intercrops. Repeated pruning keeps the quality of the edible leaves high because the new growth generally has less tough cellulose and lignin fiber than older leaves from older branches.

### *Miscellaneous tips*

- Cut the leaves you want to harvest from the plant with a sharp knife rather than tearing them. A clean cut makes a wound with much less surface of unprotected stem open to possible infection than a ragged tear.
- When thinning young plants that are too close together, snip, or pinch them off at the soil level rather than uprooting them so that you will not disrupt the root system of the neighboring plants that you want to keep growing. Thinnings make good additions to salads.
- Don't harvest during or right after a rain or overhead irrigation. When leaves are wet it is relatively easy to spread viruses from one plant to another, especially if you are harvesting and making open wounds. This is especially true for beans, peas, and other leguminous crops.
- Harvest leaves before the plant flowers. Generally when plants flower they move nutrients quickly from their leaves to their reproductive systems. As a result the protein and sugar content of the leaves declines and they become more fibrous.
- Harvest as close to when you will eat the leaves as possible. Truly fresh food is one of the great joys of gardening. Leaves and most other vegetables begin declining in nutritional value as well as flavor as soon as they are separated from the plant. Try to eat them while still near their nutritional peak.
- Harvest winter greenhouse greens in the late afternoon if possible. The low light intensity results in higher levels of undesirable nitrates. Late afternoon harvest allows the thin winter sunlight its maximum time to convert nitrates to proteins. Vitamin C levels are highest then as well, although vitamin A activity tends to be highest in the morning.