**Nutrient Deficiency and Toxicity**

A wide variety of problems can effect plant growth and health. Much of the information on this website describes diseases but this section is devoted to problems associated with either excess levels of nutrients in the soil which leads to toxicity, or a lack of nutrient within the soil which leads to deficiencies within plants. The relationship between soil nutrient levels and plant nutrient levels is complex. The ability of a plant to absorb any given nutrient is affected by pH, temperature and moisture as well as the amounts of other nutrients within the soil. For this reason, it is important to correctly diagnose symptoms of deficiency and toxicity before taking corrective action otherwise you risk solving one problem only to create another one. The information in this section of the website will help you identify nutrient deficiencies and toxicities in your plants and provide you with some tools for preventing and treating these problems.

**Why Plants Suffer from Nutrient Deficiencies and Toxicities**

Many nutrients are essential for healthy plant growth and function. They make up the cells of the plants, form plant DNA and help plants photosynthesise to produce vital sugars among many other things. When a plant doesn't have enough of a particular nutrient, it cannot make cells, DNA, sugars or any of the other important components of a plant and so this is called a nutrient deficiency. When a plant has too much of a nutrient, it might not be able to take up enough of another nutrient or the excess nutrient may make the plant sick in the same way that a person will get sick if they eat too much fatty food. Think of it this way, fat is important for humans because it allows us to take in and store certain nutrients and because it gives us energy but too much fat isn't a good thing because increases the risk of many diseases and causes a range of other problems. The same sort of thing happens in plants. Nutrient toxicities and deficiencies may occur in plants because the soil doesn't contain enough of the nutrient or because it contains too much. Not all symptoms in plants are the result of an excess or lack of nutrient in the soil though. Often, symptoms of nutrient toxicity or deficiency in plants are due to problems with the plant's uptake of one or more nutrients. This may be because something is affecting the plant's ability to absorb the nutrient (too little water prevents calcium uptake for instance) or because something is affecting the availability of the nutrient (for instance soil pH can drastically alter how much of an element in the soil is in the form that plants can use).

**How to Treat Nutrient Deficiencies and Toxicities**

Because nutrient imbalances can be a result of an imbalance in the soil, impaired or elevated availability or problems with a plant's uptake of nutrients, to treat a nutrient imbalance you first need to ensure your plants are able to uptake nutrients properly. If you suspect a nutrient imbalance in your plants and you've done everything you can to ensure your plants are capable of taking up nutrients properly and that the availability of the nutrients in the soil is appropriate for your plants, then I would always recommend you have a laboratory test your soil before taking further action. This will enable you to make absolutely sure that the problem is due to a nutrient imbalance in the soil, preventing you from wasting money on fertilisers that you don't need and from over correcting. Some labs will also provide you with tailored advice on how best to treat any problems you discover based on what you're growing and the type of soil you have, along with other environmental factors.

Below is a general guide to treating nutrient imbalances. I would encourage you to use this in conjunction with the specific information about each nutrient that can be found on this website.

**7 Steps to Treating Nutrient Imbalances**

1. Check the visual symptoms to determine which nutrients might be causing the problem.
   * Taking a photo is also a great idea as you can more easily monitor the progress of any treatments if you don't have to rely on your memory of what the plants look like before you did anything.
2. Check and amend if necessary, the soil's pH, temperature and moisture level. Ensure the plant is getting the right amount of light. Add organic matter to the soil.
   * If you needed to adjust the pH, add water or improve drainage, warm the soil up (eg. using a cold frame) or move the plant to a different spot (or prune overhanging branches or add shade cloth) then wait 3-4 weeks and if symptoms haven't improved, move to step 3.
3. Read the page or pages on this website that relate to the nutrient(s) you believe are in excess or are deficient. Follow the suggestions for improving the condition that don't involve adding fertiliser. Wait 3-4 weeks and see if there's any change before moving to step 4.
4. Have your soil tested by a laboratory to definitively determine what nutrient deficiencies or excesses there are.
   * If the soil tests show that all the nutrients are in the normal range, have some plant tissue tested. If the tissue test shows a nutrient imbalance, something else (such as a pesticide) is causing the plant to uptake an abnormal amount of nutrient and you'll need to fix that problem.
   * If the test shows that the plant has the correct amount of nutrients, something else is causing the symptoms. The plant may have a disease or may have special requirements that you're not meeting (some plants need unusually acidic soil for instance).
5. If the soil test shows that the soil has too much or not enough of one or more nutrients, follow the directions on the relevant page(s) of this website to determine which fertilisers would be best to use. For symptoms that affected older leaves first, you should see a difference within 2-4 weeks if you used a quick release fertiliser. For symptoms that effect younger leaves first, affected leaves will likely stay the same but new leaves should appear normal.
6. Regularly add organic matter to the soil and the keep it mulched, to help improve the soil longer term.
7. A follow up soil test in 6-12 months would be a good idea as it will enable you to determine whether you've been mangling the soil appropriately and whether you need to additional fertiliser until the soil fertility increases (probable in really poor or degraded soils).

**How to Prevent Nutrient Imbalances**

Often the best defence is a good offence and nutrient imbalances are no exception to this. The best treatment for a nutrient toxicity or deficiency is to prevent it from ever occurring.

**Preventing Nutrient Deficiencies**

Nutrient deficiencies often occur when soil is neglected. Whether you're a gardener or a farmer, you can look after your soil by preventing soil compaction and replacing any nutrients that are removed.

To prevent soil compaction, you need to ensure you don't walk on your beds and that heavy machinery doesn't run over your beds. To do this, make sure you have well defined paths. Also, rain can compact bare soil so make sure your soil is always either growing plants (this includes green manure crops) or is well mulched.

If plant matter is being removed from the soil, through harvesting of flowers, food or other plant products, then the nutrients that are removed in the process need to be replaced, preferably by adding organic matter to the soil. Organic matter may be plant waste, compost, manure or anything else that was once living.

Different plant species require different amounts of each nutrient so companion planting and crop rotation are also important tools for preventing nutrient deficiencies. It's also important to note that while pesticides don't generally remove nutrients from the soil, glyphosphate and other similar pesticides work by preventing the uptake of nutrients by plants and it can be difficult to prevent plants from being contaminated with pesticides when they're being used on nearby weeds or insect pests. Not using such pesticides is a sure way to stop them from causing nutrient deficiencies though.

**Preventing Nutrient Toxicities**

Under normal circumstances, nutrients typically only build up in the soil to the point of causing toxic effects in plants, when they're added to the soil by humans. Inappropriate use of fertilisers is one obvious way nutrients may be added to the soil but nearby mining and heavy traffic can increase the amount of some nutrients in the soil and can also introduce toxic contaminants to the soil. What some people don't realise is that some pesticides, even those allowed in organic gardens, can also cause nutrient toxicities. Copper based fungicides for instance can cause toxic levels of copper to build up in the soil. If you really need to use a pesticide on your property, make sure you read the instructions carefully and research the possible side effects of the product before you use it so that you can prevent these sorts of side effects.

**Six Key Things to Know About Nutrient Imbalances**

1. Many nutrient imbalances share similar symptoms. A good example is nitrogen an sulfur. When plants are deficient in either nutrient, leaves turn yellow. They can be distinguished by the location of yellow leaves though.
2. Multiple imbalances can occur at the same time. Your plants may suffer from multiple deficiencies at the same time, particularly if incorrect pH or another factor is causing the deficiencies. Your plants might also suffer from a toxicity and deficiency at the same time, especially since nutrient toxicities can result in deficiencies of other nutrients. As an example, excess phosphorus often causes zinc deficiencies.
3. Different plant species (or even cultivars) will respond to deficiencies and toxicities in different ways. Some types of plants are more tolerant of certain imbalances or may show different symptoms. For instance, strawberry leaves typically turn red as a result of phosphorus deficiency while corn leaves turn purple.
4. Other plant problems may cause symptoms that are similar to nutrient imbalances. Some diseases produce similar symptoms to nutrient imbalances but too much or too little water, soil compaction and insect attack can also mimic nutrient imbalance symptoms. Pesticide (including herbicide) damage can also produce similar symptoms.
5. Nutrient imbalances may be silent for some time. That is, a plant may be suffering from a deficiency or toxicity for some time before symptoms become visible. Sometimes, the first symptom of a problem is increased pest damage resulting from less than healthy plants.
6. Symptoms that you see may differ from 'typical' symptoms. Scientists can take photos of plants grown under laboratory conditions with an intentional deficiency or toxicity. In your garden or on your farm, symptoms may look different for any number of reasons including but not limited to:
   * Different species
   * Different soil type
   * The presence of other nutrient imbalances
   * Too much or too little water or light.

**Definitions**

**Three Important Nutrient Imbalance Terms**

**Chlorosis**

Chlorosis occurs when there isn't enough chlorophyll in a leaf. Chlorophyll is the green chemical that enables plants to produce sugars so when there isn't enough chlorophyll in a leaf, it turns yellow.

**Necrosis**

Necrosis is the term given to dead plant tissue. Necrotic tissue, which may be on leaves or other parts of the plant, will appear brown and after some time, will dry up.

**Interveinal**

Interveinal means 'between the veins'. On this website you may see the term 'interveinal chlorosis' and this means yellowing between the veins of a leaf. 'Interveinal necrosis' means that there are dead patches between the leaf veins.

**Other Useful Terms**

**Cation**

A positively charged element or combination of elements. In the soil cations include:

* Ammonium NH4+
* Calcium Ca2+
* Magnesium Mg2+
* Potassium K+
* Sodium Na+

**Anion**

A negatively charged element or combination of elements. In the soil anions include:

* Carbonate CO32-
* Nitrate NO3-
* Sulfate SO42-
* Phosphate PO43-

**Macronutrient**

Macronutrients are those nutrients that are required in large amounts by plants to complete their normal life cycle and/or because they are part of an essential part of the plant (or an essential compound that the plant makes).

**Structural Macronutrients**

Carbon (C), hydrogen (H) and oxygen (O) are the nutrients used in the physical structure of plants and are thus called structural macronutrients.

**Primary Macronutrient**

Primary macronutrients are heavily used by plants, are required for them to grow and are most likely to be added to the soil in fertilisers because deficiencies in these nutrients are likely to limit the yield of plants. All may be leached from the soil fairly easily as well. The three primary macronutrients are nitrogen (N), phosphorus (P) and potassium (K).

**Secondary Macronutrient**

A deficiency in any of the secondary macronutrients is less likely to occur because slightly lower amounts are required by most plants when compared with the primary macronutrients but these nutrients are nevertheless required by plants in fairly large amounts. The secondary macronutrients are calcium (Ca), magnesium (Mg) and sulfur (S).

**Micronutrient**

Micronutrients are those elements essential for plant growth which are required in only very small amounts. They may also be referred to as trace elements. The commonly recognised micronutrients are boron (B), copper (Cu), iron (Fe), chlorine (Cl), manganese (Mn), molybdenum (Mo) and zinc (Zn). Nickel (Ni) has only been recognised as a micronutrient relatively recently and its status as an essential nutrient is still contested by some.

**Aluminium**

Aluminium is used by some plants but it is not an essential nutrient and it is toxic to many plants. Your soil will contain some aluminium as about 7% of the Earth's crust is aluminium but ideally, your plants shouldn't take up much of this aluminium.

**Aluminium Toxicity**

High levels of aluminium are toxic to some plants and are associated with acidic soil. Indeed, most of the problems associated with acidic soil are due to aluminium toxicity. Aluminium has the following affects on plants:

* Roots - aluminium decreases the amount of roots a plant produces and it also reduces the function of roots that are produced. This means that plants are not able to uptake as much water or as many nutrients as they require.
* Phosphorus - aluminium prevents plants from being able to uptake phosphorus.
* Calcium - aluminium prevents plants from being able to uptake and use calcium.
* Magnesium - aluminium also prevents plants from being able to uptake and use magnesium.
* Sulfur - aluminium reduces the amount of sulfur that can be taken up by plants.

**Symptoms of Aluminium Toxicity**

Plants will become stunted if they absorb too much aluminium. They may also show symptoms of [phosphorus deficiency](https://plantprobs.net/plant/nutrientImbalances/phosphorus.html), [calcium deficiency](https://plantprobs.net/plant/nutrientImbalances/calcium.html), [magnesium deficiency](https://plantprobs.net/plant/nutrientImbalances/magnesium.html) or [sulfur deficiency](https://plantprobs.net/plant/nutrientImbalances/sulfur.html). Plants suffering from aluminium will frequently also suffer from [manganese toxicity](https://plantprobs.net/plant/nutrientImbalances/manganese.html). This is usually due to a low soil pH and is not believed to be a result of excess aluminium itself.

**Treating Aluminium Toxicity**

If the pH of soil is greater than 5.5 (when measured in calcium chloride which is the most common way pH is measured by laboratories performing soil tests - this is roughly pH 6-6.5 when measured in water or with a probe) aluminium is not as available to plants so is less likely to cause toxicity. As such, if a laboratory soil test reveals that the pH of your soil is less than 5.5 or a home pH test reveals that the pH is less than 6, lime can be added to soil to prevent or treat aluminium toxicity. Organic matter, when it accounts for greater than 5% of the soil, can tie up aluminium making it inaccessible by plants, so adding organic matter can be a supplemental means of reducing aluminium toxicity. If raising soil pH is ever difficult, aluminium tolerant plants can be grown. For instance, hydrangeas need aluminium in order to produce blue flowers so they are a good choice for soils that contain elevated levels of aluminium.

**Arsenic**

Arsenic is a toxic compound and it is most toxic in its inorganic form. Long‑term exposure to arsenic from drinking‑water and food can cause cancer and skin lesions. It has also been associated with developmental effects, cardiovascular disease, neurotoxicity and diabetes.[[1]](https://plantprobs.net/plant/nutrientImbalances/arsenic.html#ref1)

**Arsenic in Soil and Plants**

Arsenic naturally occurs in the soil and elsewhere in the environment and it is the 20th most common element on Earth. Industrial activity (such as mining) can increase natural levels. Arsenic is also found in CCA treated timber, termite control products and some herbicides designed for use on lawns. Extensive research has shown that arsenic is 'safe' or tolerable if ingested at rates below two µg/kg of body weight per day (World Health Organisation limit), or three µg/kg of body weight per day (Food Standards Australia limit). The NSW Department of Primary Industries suggests that agricultural soil should have less than 20 mg of arsenic per kg of soil. Different guidelines may be available in your area but this is a good general guide. If your soil has an arsenic concentration of more than 10 mg/kg, it would be a good idea to order a plant tissue test and seek expert advice on whether the amount of arsenic in your home grown food constitutes a health risk.

If you are not growing food in your garden or the food you grow makes up less than 10% of the fruit and vegetables you eat, Australian guidelines recommend a soil lead value of less that 100 mg/kg.[[2]](https://plantprobs.net/plant/nutrientImbalances/arsenic.html#ref2) Environmental protection agencies in California, Canada, Norway and the United States publish guidelines for arsenic in soil as well: 0.07 mg/kg, 12 mg/kg, 12 mg/kg and 0.61 mg/kg respectively.

**Dealing with Excess Arsenic in the Soil**

There are a number of ways to reduce the risk of ingesting arsenic from the soil (via ingesting plants and plant matter grown in that soil).

1. Garden in raised beds. Raised beds containing imported (non contaminated) soil will not absorb arsenic from the ground soil below ‑ provided CCA treated timber is not used for the structure of the bed. To be on the safe side, edible plants grown in raised beds should not be able to sink a large proportion of their roots into the soil below the garden bed. Raised bed heights should thus be sufficient to cover the majority of root growth. Where there is a concern, plant tissue testing will demonstrate whether plants are absorbing arsenic in excess of accepted levels.
2. Choose crops carefully. Studies have shown that certain types of crops are more likely to absorb arsenic than others. The CSIRO[[3]](https://plantprobs.net/plant/nutrientImbalances/arsenic.html#ref3) notes that the above ground fruits of plants grown in contaminated soil (such as tomatoes, cucumbers and grapes) do not contain arsenic whereas root vegetables (carrots and beetroot) do. The arsenic accumulates mostly within the skin of these vegetables so can be removed prior to consumption through peeling. The arsenic is also known to be in a safer, organic form.
3. Bioremediate the soil. Certain plants accumulate large amounts of toxins without any ill effects. These plants can be removed when they reach maturity and the soil toxins with them. Over time, repetition of this cycle reduces the amount of the toxin in the soil, provided soil isn't being continuously contaminated (from uphill water run off or herbicide use for instance). *Pityrogramma calomelanos* var. *austroamericana* is an arsenic super accumulator that could be used for this purpose.

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**Boron**

Boron is an essential plant [micronutrient](https://plantprobs.net/plant/nutrientImbalances/definitions.html). It is used by plants during cell division and is required for development of tissue near the tips of shoots and roots. It is also required for the growth of the pollen tube during flower pollination and thus fruit and seed production. Boron is thought to increase nectar production by flowers so it is important for attracting pollinating insects. It is also required for good cell structure and as a result, the tissue of boron deficient plants often breaks down prematurely resulting in brown flecks, necrotic spots, cracking and corky areas in fruit and tubers. Excess boron inhibits seed germination.

A wide variety of factors can influence the availability of phosphorus including:

* pH ‑ boron is less available in moderately alkaline soil and more available in acidic soil.
* Water ‑ high rainfall and excess irrigation can leach boron from the soil.
* Organic matter ‑ organic matter provides boron as it breaks down and also improves the ability of soil to hold boron.
* Moisture ‑ low levels of soil moisture inhibit the uptake of boron.
* Calcium ‑ some research indicates that excess calcium can inhibit the uptake of boron by plants.
* Nitrogen ‑ severe nitrogen deficiency may reduce a plant's ability to uptake boron.

Ideally, for healthy and productive soil you should aim for a boron concentration of 0.5‑4 mg/kg. Some laboratories may only be able to detect concentrations as low as 4 mg/kg and while this is sufficient for determining whether soil has an excess, such information cannot tell you whether there is a soil deficiency. If you suspect your soil does not have enough boron, make sure you check that the laboratory you chose can perform a test with a low enough detection limit (the test should measure down to 0.5 mg/kg or lower). If the concentration of boron in your soil is greater than 4500 mg/kg it would be a good idea to have your home grown food tested for boron and then seek expert advice about any action you might want to take.

**Boron Deficiency**

Boron is easily leached from soil so is most likely to be deficient in sandy soils located in areas of high rainfall. A lack of organic matter in the soil will also increase the likelihood of plant boron deficiencies.

**Symptoms of Boron Deficiency**

The symptoms of boron deficiency can vary greatly between different species but often new leaves will be discoloured ‑ usually they will be a reddish colour though they may just be [chlorotic](https://plantprobs.net/plant/nutrientImbalances/definitions.html). Often new leaves will develop [necrotic](https://plantprobs.net/plant/nutrientImbalances/definitions.html) spots and will be wrinkled. Frequently, the buds at the ends of stems (apical buds) will die. In severe cases, older leaves may become irregularly shaped. Root [necrosis](https://plantprobs.net/plant/nutrientImbalances/definitions.html) may result in reduced growth of the whole plant. Plants affected by boron deficiency will most likely fail to set seed regardless of how many flowers they produce though flower production is frequently reduced.

**Treating Boron Deficiency**

As with any plant problem, the first thing you should do is check that the pH is appropriate for the plant ‑ usually close to neutral. Boron is most available when the soil pH is between 5.5 and 7 and when the pH is 10.5 or greater. Provided the pH is between 4 and 7.5 though, sufficient boron should be uptaken by most plants.

You should also add lots of organic matter to your soil and check that you are only watering when the soil is dry or nearly dry (depending on the water requirements of your plants).

If symptoms persist, it would be a good idea to have your soil tested for boron, calcium and nitrogen at the very least. If nitrogen levels are low, take steps to [boost the level of nitrogen in your soil](https://plantprobs.net/plant/nutrientImbalances/nitrogen.html). Likewise, if calcium levels are excessive, cease any practices that may be contributing to the high levels (this includes the addition of calcium containing fertilisers and other soil amendments such as gypsum, limestone and dolomite).

If symptoms still persist and the soil test revealed low levels of boron, then you can apply boron containing soil amendments. Adding even more organic matter is always a good idea but by this point you may require an inorganic source of boron such as a foliar spray (eg polybor), boric acid or borax.

**Boron Toxicity**

Boron toxicity most often occurs either as a result of excess boron containing fertiliser use or because the soil is naturally high in boron. Soil in areas that were previously under sea water are more likely to be naturally high in boron. Irrigation water may also be a source of boron but soil may build up high levels of boron if it is contaminated with wastes from surface mining, fly ash or industrial chemicals.

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Symptoms of boron toxicity initially consist of [chlorosis](https://plantprobs.net/plant/nutrientImbalances/definitions.html) along the margins of leaves that progresses towards the veins. When boron toxicity is severe, leaves may blacken and then die between the veins.

**Treating Boron Toxicity**

As indicated above, boron is most available when the soil pH is between 5.5 and 7 and when the pH is 10.5 or greater. It is still fairly easily absorbed between pH 4 and 7.5 though and at pH 10 and above. As such, if your soil is very alkaline, boron toxicity is much more likely and plants are also likely to experience nutrient deficiencies as well, which means that plants are under greater stress. So the first step to treating boron toxicity is to make sure that the soil pH is close to neutral. While your plants may still uptake a similar amount of boron at pH 7, they will at least also be able to take up other nutrients more easily and this will help to strengthen them.

Once the soil pH has been neutralised if required, it would be a good idea to have the soil tested to determine both the boron and calcium concentrations. If the soil definitely contains excess boron but it also lacks calcium then applications of calcium may help to reduce the amount of boron being uptaken by the affected plants.

Once excess soil boron has been diagnosed, take some time to learn the source of the problem. If contamination (perhaps through irrigation with contaminated water) is the cause, take steps to prevent any further contamination and then monitor the soil boron level over a number of months. This may be enough to rectify the problem. If not, it may be possible to leach the excess boron from the soil but this is laborious, expensive, may result in other nutrient imbalances and may not result in a permanent improvement.

If you cannot correct soil boron levels or it is impractical to do so, it would be a good idea to limit your selection of plants to species that are tolerant of higher boron levels. In a garden situation you might consider building raised beds and purchasing healthy, nutrient balanced soil. You could also build your own soil overtime (to fill raised beds with or to use as top soil) through composting etc. but of course you'll need to make sure that you don't use organic waste grown on your property otherwise the compost will end up high in boron too. Purchasing soil is the quickest option but of course it is more expensive. If you have a large property, growing tolerant crops is the most suitable solution.

**Cadmium**

Cadmium is a toxic element used in the manufacture of batteries and is found in cigarette smoke, some paints, soil zinc additives, some fertilisers (especially those that contain phosphorus) and some manures. Industrial activity, such as mining, can increase soil cadmium levels. The acute symptoms of cadmium ingestion include stomach irritation and cramps, nausea, vomiting and diarrhoea, headaches, flu‑like symptoms, swelling of the throat and tingling hands. Chronic ingestion of cadmium can cause kidney disease and bone weakness. Ingestion of large amounts of cadmium can damage the kidneys, liver and heart and may even cause death. Cadmium is carcinogenic when inhaled but ingestion is not thought to cause cancer.[[1]](https://plantprobs.net/plant/nutrientImbalances/cadmium.html#ref1)[[2]](https://plantprobs.net/plant/nutrientImbalances/cadmium.html#ref2)

**Cadmium in Soil and Food**

In Australia, the upper limit of cadmium allowed in root, tuber and leafy vegetables is 0.1 mg of cadmium per 1 kg of produce.[[3]](https://plantprobs.net/plant/nutrientImbalances/cadmium.html#ref3) The allowed value in your area may be different but you can use this value as a guide. The amount of cadmium in soils is generally low but once it has been added to the soil, it can take between 100 and 1000 years for the levels to drop by 50%. When cadmium is present in soil, it is more available to plants if the soil is sandy, acidic or low in organic matter.[[2]](https://plantprobs.net/plant/nutrientImbalances/cadmium.html#ref2) It is recommended that soil contain less than 1 mg of cadmium for every 1 kg of soil. If the concentration of cadmium in your soil is greater than 20 mg/kg[[4]](https://plantprobs.net/plant/nutrientImbalances/cadmium.html#ref4) it would be a good idea to have your home grown produce analysed and then seek expert guidance on whether any cadmium detected constitutes a health risk.

**Preventing Contamination of Soil and Food with Cadmium**

By observing the following, it is possible to prevent contamination of soil and produce with cadmium provided the heavy metal does not leach into soil from an external source (a mine for instance):

* Use low cadmium fertilisers and only use the minimum amount required for healthy plant growth
* Ensure soil pH is close to neutral (add lime if the soil is too acidic)
* Ensure the soil always contains an adequate amount of zinc
* Continuously incorporate plenty of organic matter into the soil
* If soil cadmium levels are elevated, grow plant varieties that take up less cadmium

Leafy vegetables like lettuce, cabbage and spinach take up the most cadmium. Root crops such as carrots and potatoes take up less but fruiting plants take up the least amount of cadmium. As such, [this method for dealing with arsenic contamination](https://plantprobs.net/plant/nutrientImbalances/arsenic.html) (using raised beds for most vegetables and only growing fruit trees and bushes in the ground) can be used for cadmium if desired.

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**Calcium**

Calcium is a [secondary plant macronutrient](https://plantprobs.net/plant/nutrientImbalances/definitions.html) and is vital for healthy plants. It is required for the formation of new cells so is needed in order for roots, stems and leaves to grow. It is also used by plants when they respond to pest and disease attacks. Calcium deficiency can negatively affect the ability of legumes to associate with nitrogen fixing bacteria so it is perhaps of greater importance for legumes than to other plants but it is also required for nitrogen uptake in all types of plants. A number of plant enzymes also require calcium.

Factors affecting calcium availability include:

* pH - calcium is less available in acidic soils and more available in alkaline soils. Additionally, if the soil is alkaline, excess calcium can bind to phosphorus preventing it from being taken up by plants.
* Cation exchange capacity - the more clay and organic matter in soil, the more [cations](https://plantprobs.net/plant/nutrientImbalances/definitions.html) and thus calcium it can hold.
* Other [cations](https://plantprobs.net/plant/nutrientImbalances/definitions.html) - excess levels of other [cations](https://plantprobs.net/plant/nutrientImbalances/definitions.html) can prevent plants from taking up calcium. This is particularly true of sodium.
* Moisture - a lack of water in the soil prevents the uptake of calcium by plants.
* Temperature - plants are less able to take up calcium when the soil is cold.
* A soil's parent material - soils are derived from different materials. If soil is made from limestone or another high calcium material, it will usually have more calcium. If soil is made from sandstone or shale, it will usually have lower levels of calcium.

Ideally, for healthy and productive soil you should aim for a calcium concentration of at least 5 meq/100g (milliequivalents - this is a special term used to describe the amount of some elements in soil).

**Calcium Deficiency**

Calcium deficiency is most likely to occur early in spring when the soil is cold and/or when plants are grown in acidic soil. Some soils are naturally low in calcium and plants grown in such soils are also more likely to develop symptoms of calcium deficiency. Plants are also more susceptible to calcium deficiency during periods of drought and when soil moisture is inconsistent. This may be a result of sporadic rainfall or irregular irrigation. When one or more of the above factors are present, clay soil can further increase the likelihood of calcium deficiency as it can inhibit good root development and thus decrease the amount of soil available for a plant to use to uptake water, calcium and other nutrients.

**Symptoms of Calcium Deficiency**

The most common symptom of calcium deficiency that is recognised by gardeners is blossom end rot - a 'disease' that causes fruit tissue to die at the flower end of the fruit. Tomatoes are most commonly affected but squashes and melons are also often affected. Lack of calcium in the soil is rarely the cause of blossom end rot however. It is more commonly a result of uneven watering - lack of water prevents calcium uptake. This is an important piece of information to note, particularly for soils that have marginal calcium levels.

Other symptoms of calcium deficiency (usually more a serious deficiency) may include [chlorosis](https://plantprobs.net/plant/nutrientImbalances/definitions.html) of new leaves (blotches rather than all over each leaf), [necrosis](https://plantprobs.net/plant/nutrientImbalances/definitions.html) along the edges of leaves and death of leaf buds. The newest leaves may also appear hooked. Root growth is often affected and so this may result in stunted plants.

**Treating Calcium Deficiency**

Calcium deficiency in plants is best treated by ensuring soil has a neutral or near neutral pH and that the moisture level in the soil is consistent. Calcium is most available between pH 7.5 and 9 but good uptake should still occur between pH 6.5 and 9.5 and so you should add either lime or sulfur (or another acidifying or alkalising agent) if the pH is not within this range. Supplemental watering needs to be consistent where rainfall is sporadic.

If symptoms are visible early in spring, they may be alleviated by warming the soil. Mulch can assist with the task when plants are already in the ground. If calcium deficiency in early spring is common on your property, you may be able to prevent it by placing low greenhouses/cold frames or even a sheet of clear plastic over the soil a few weeks before sowing seeds or transplanting seedlings in order to raise the soil temperature. You'll need to mulch well when transplanting seedlings or just after seeds sprout in order to maintain the heat.

If fertilisers that are high in other [cations](https://plantprobs.net/plant/nutrientImbalances/definitions.html) (such as magnesium and potassium) are being applied, these should be exchanged for alternative fertiliser (if magnesium is high and you need to increase the soil pH, don't use dolomite as it can upset the calcium to magnesium balance further). If irrigation water is salty (bore water is an example of water that is often salty) and you really can't get by with only natural rainfall consider using an alternative source of water (installing a rainwater tank is a good option).

If these factors do not fix the problem and a soil test reveals your soil has a calcium concentration of 5meq/100g or less, calcium fertilisers can be applied. Organic fertilisers containing a decent amount of calcium include egg shells, wood ash and bone meal. Rock dust and gypsum also contain calcium and gypsum is particularly useful on some clay soils. Inorganic sources of calcium include calcium nitrate, burnt lime, hydrated lime and even superphosphate (which is calcium phosphate).

**Calcium Toxicity**

Excess calcium is unlikely to cause toxicity in and of itself. It can reduce the uptake of other nutrients (mostly [cations](https://plantprobs.net/plant/nutrientImbalances/definitions.html)) however, potentially causing deficiencies in other nutrients. If such a scenario is suspected, stop any applications of calcium containing materials (including gypsum) and supplement the soil with a fertiliser containing the lacking mineral if appropriate. Always ensure the pH of the soil is appropriate for the plants you are growing. In particular, it would be beneficial to reduce the soil pH if it is a little too high.

# Calcium to Magnesium Ratio

There has been a lot of interest in ideal soil ratios. It has been shown however that such a thing is unlikely to exist. Having said that, too much of one or more [cations](https://plantprobs.net/plant/nutrientImbalances/definitions.html) can prevent the uptake of other [cations](https://plantprobs.net/plant/nutrientImbalances/definitions.html). As such a minimum calcium to magnesium ratio has been established and is generally agreed to be useful in preventing nutrient deficiencies. Ideally, the calcium to magnesium ratio should be greater than 3 for healthy soils. If the value is less than 2, plants will find it difficult to take up potassium. The soil structure may also degrade due to dispersion.

Remedial action includes boosting calcium levels through the addition of gypsum or lime. If the pH of the soil is neutral or alkaline, don't use lime as this will increase the pH further. As such, gypsum is probably the best material to use for boosting calcium levels gently. If soil is very calcium deficient, a specialised calcium fertiliser may be used. If magnesium levels are high and the pH is low, dolomite may seem to be a useful amendment but avoid the temptation because it can actually upset the calcium to magnesium ratio further.

# Chlorine

You may not realise it but chlorine is classed as a plant [micronutrient](https://plantprobs.net/plant/nutrientImbalances/definitions.html) meaning that it is essential for the proper growth of plants. It is important to note though, that it is the ion (Cl‑) rather than the gas (Cl2) that is used by plants. In particular, chlorine is important for plant photosynthesis as it is involved in the opening and closing of stomata (pores in leaves that enable plants to take in and release carbon dioxide, oxygen and other gases as required. It also helps ensure leaves are firm.

## Chlorine Deficiency

It has only been fairly recently that the effects of chlorine deficiency have begun to be documented. Soil is unlikely to be deficient in chlorine in coastal areas (due to the large amounts of sodium chloride (salt) in the soil) but sandy, inland soil may become deficient in chlorine if rainfall is high or plants are irrigated too frequently.

### Symptoms of Chlorine Deficiency

Chlorine deficiency results in blotchy leaf [chlorosis](https://plantprobs.net/plant/nutrientImbalances/definitions.html) and [necrosis](https://plantprobs.net/plant/nutrientImbalances/definitions.html). Chlorine deficiency can be distinguished from other nutrient imbalances because leaves will exhibit characteristic distinct and abrupt boundaries between the affected and healthy tissue. Severe cases of chlorine deficiency may result in bronzing and/or wilting of leaves though these are not reliable symptoms.

### Treating Chlorine Deficiency

As with any suspected nutrient imbalance, if you think your plants may be deficient in chlorine you should check that the soil is neutral with a pH of around 7 (unless the affected plant requires special pH conditions ‑ azaleas and blueberries require acidic soil for instance). It's always a good idea to also check that the soil isn't getting waterlogged or too dry, that it isn't compacted and that there is plenty of organic matter in it.

If symptoms persist, see if you can find a laboratory that will test your soil to determine the amount of chlorine in it. Not all labs will do this but it's worth hunting around for one that will so that you can be sure to correctly diagnose the problem. If the soil test shows that your soil is lacking chlorine, you can then use a chlorine containing fertiliser to amend the soil. Specialist fertiliser suppliers should be able to produce a custom fertiliser to meet your needs but if your soil has low to moderate levels of potassium, you may be able to use muriate of potash (potassium chloride or KCl) to increase the amount of both chlorine and potassium in the soil ‑ you just need to be careful that you don't end up with excess levels of potassium in the soil. Do not use table salt (sodium chloride or NaCl) to increase soil chlorine levels as excess sodium levels in soil can be detrimental to plant health.

## Chlorine Toxicity

Chlorine toxicity can occur naturally when plants are grow in coastal soils and near chlorinated pools (though much of the damage associated with chlorinated pools is due to the vapours coming into contact with leaves rather than because the plant has uptake too much chlorine).

### Symptoms of Chlorine Toxicity

Chlorine toxicity will usually result in [necrosis](https://plantprobs.net/plant/nutrientImbalances/definitions.html) along leaf margins and smaller than usual leaves and plants. Symptoms are usually seen on older leaves first. In some species, [chlorosis](https://plantprobs.net/plant/nutrientImbalances/definitions.html) may also occur.

### Treating Chlorine Toxicity

As always, your first port of call is the soil pH. You should ensure the pH of your soil is around 7. It's also a good idea to make sure your soil isn't compacted and that it drains freely. Plants may struggle to uptake some other from the soil if there is a significant imbalance so it's a good idea to check that your soil contains adequate amounts of nutrients that form in the soil such as nitrogen, sulfur and phosphorus. Chlorine is easily leached from the soil so temporary chlorine toxicity (perhaps through accidental contamination as a result of excess fertiliser use or a pool chemical spill) may be alleviated through frequent watering. Just be sure to replenish other elements that may also be leached from the soil in this way.

If your soil contains high levels of chlorine because you live on the coast, you may need to grow chlorine tolerant plant species. You could also grow plants in containers and regularly replace the potting mix when chlorine levels rise.

**Chromium**

**Chromium in Soil and Plants**

Chromium is a naturally occurring element in rocks and soil. Natural soil typically contains between 10 and 50 mg of chromium for every kg of soil. Chromium can exist in its elemental form (chromium 0) as well as chromium III and chromium VI ‑ the Roman numerals denote the valency. Chromium is toxic in high amounts to both plants and humans but the toxicity depends on the valency; chromium VI being substantially more toxic. Chromium affects seed germination, plant growth, photosynthesis and the uptake of a variety of nutrients.[[1]](https://plantprobs.net/plant/nutrientImbalances/chromium.html#ref1)

**Chromium in Humans**

It is important to note that chromium is beneficial to humans in very small amounts (in fact it has been deemed an essential element) as it is involved in the action of insulin.[[2]](https://plantprobs.net/plant/nutrientImbalances/chromium.html#ref2) As it is naturally present in a wide range of foods, a deficiency is unlikely.

Inhalation of chromium VI causes a variety of effects but this is unlikely to be a problem in a garden situation except if large amounts of very dry soil are inhaled. Chromium can cause skin sensitisation and cancer, however research has demonstrated that there is very little risk of this when exposure is via contact with contaminated soil.[[3]](https://plantprobs.net/plant/nutrientImbalances/chromium.html#ref3) Ingestion of chromium can cause kidney and liver damage, stomach ulcers, vomiting, haemolysis, heart problems and possibly reproductive problems.[[4]](https://plantprobs.net/plant/nutrientImbalances/chromium.html#ref4)

**How Much Chromium is Too Much?**

If less than 10% of the fruit and vegetables you eat comes from your garden and the concentration of chromium in your soil is greater than 100 mg/kg,[[5]](https://plantprobs.net/plant/nutrientImbalances/chromium.html#ref5) it would be a good idea to have your home grown produce analysed and then seek expert advice on whether any chromium detected constitutes a health risk. If more than 10% of the fruit and vegetables you eat comes from your garden, you may wish to test some of your produce even if your soil contains less than that amount. The Canadian Soil Quality Guidelines for the Protection of Environmental and Human Health (2007) recommends that soil in residential areas and parklands should contain less than 64 mg/kg of total chromium and 0.4 mg/kg of Chromium VI.[[6]](https://plantprobs.net/plant/nutrientImbalances/chromium.html#ref6) These guidelines specify the same values for agricultural land[[6]](https://plantprobs.net/plant/nutrientImbalances/chromium.html#ref6) so if you are a farmer growing produce for commercial purposes and your soil contains chromium in excess of either of these values, I would recommend you seek expert advice for your situation.

**Treating Chromium Toxicity**

In the event that high chromium levels are detected in soil, there are some options for remediation. Nutrient deficiencies resulting from chromium toxicity can be ameliorated by mycorrhizas (beneficial fungal associations).[[1]](https://plantprobs.net/plant/nutrientImbalances/chromium.html#ref1) As a result, digging should be kept to a minimum on soils that contain high levels of chromium. It may be possible to remediate soils high in chromium using *Albizia amara*.[[1]](https://plantprobs.net/plant/nutrientImbalances/chromium.html#ref1) As with other forms of contamination, vegetables and fruits can be grown in raised beds containing clean soil.

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# Cobalt

Cobalt is a trace element in plants (it has not been proven to be essential for plant life). It is a component of a number of enzymes and increases the drought resistance of seeds. In legumes, cobalt is important for nitrogen fixation by the bacteria that associate with legumes. It is also a component of vitamin B12 so is important for human consumption. Some research suggests that cobalt plays a role in the production of ethylene by plants. Interestingly, high levels of cobalt can reduce the amount of cadmium that is uptaken by plants. On average, 1 kg of soil contains about 8 mg of cobalt though this amount varies widely around the Earth from 0.1‑70 mg/kg. Ideally, for healthy and productive soil, the concentration of cobalt should at least 1‑2 mg/kg. Anything less than that will likely result in cobalt deficient plants even if the low level of soil cobalt is natural. If the concentration of cobalt in the soil is greater than 100 mg/kg, it would be a good idea to have some plant tissue analysed and then seek expert guidance on any action you should take.

## Cobalt Deficiency

Not a lot is known about cobalt deficiency currently, though research produces new information all the time. Cobalt deficiency in plants is more likely to affect the animals (or people) eating the plants than it is to affect the plants themselves.

### Symptoms of Cobalt Deficiency

Cobalt deficiency may result in reduced seed germination in dry conditions and reduced plant growth. In legumes, cobalt deficiency may result in symptoms of nitrogen deficiency.

### Treating Cobalt Deficiency

Owing to the vague symptoms of cobalt deficiency, a problem is usually only diagnosed by soil test. If a soil test reveals a cobalt deficiency first ensure that the soil pH is around 7 so that the affected plants will be able to to uptake the cobalt that is in the soil more easily. You should also add some organic matter to the soil. You may then apply a cobalt containing fertiliser such as cobalt sulfate or a general trace element fertiliser that contains cobalt.

## Cobalt Toxicity

Cobalt toxicity seems to be more common than cobalt deficiency although prevalence does depend on the area (in some areas, cobalt deficiency is more common).

### Symptoms of Cobalt Toxicity

High levels of cobalt can result in iron deficiency in plants so symptoms are often those of iron deficiency. Cobalt can also produce its own toxicity symptoms and these include loss of leaves from a plant, pale coloured leaves and discoloured veins.

### Treating Cobalt Toxicity

As always, ensure the soil has a neutral pH (around 7) and contains plenty of organic matter. Other than that, there's not a lot that you can do if your soil naturally contains a lot of cobalt although it is unlikely that it will naturally contain so much cobalt as to cause toxicity symptoms in plants. As such, you should try to determine whether something is boosting the levels. Check your irrigation water and any run off that enters your property for instance. It would also be a good idea to check how much nickel is in your soil. If the soil has a low level of nickel, adding nickel to the soil may help reduce symptoms of cobalt toxicity.

**Copper**

Copper is a [micronutrient](https://plantprobs.net/plant/nutrientImbalances/definitions.html) in plants and an important constituent, in small amounts, of the human diet. It is a naturally occurring element in the soil and it can be found as a metal or in a variety of ores. It is a constituent of many man made alloys and is used in wire and some coins.

Copper plays a range of roles in plants. It facilitates respiration and photosynthesis and is important for plant metabolism. It is a component of a variety of enzymes and plant cell walls so it is important for plant strength. Copper also affects the flavour, sugar content and storage life of fruit.

A variety of factors can affect the availability of copper including:

* Root growth ‑ copper doesn't move through soil easily so anything that reduces root growth also prevents plants from taking up copper.
* pH ‑ copper availability is higher in acidic soils and lower in alkaline soils.
* Organic matter ‑ organic matter reduces the availability of copper (though it is released as organic matter breaks down).
* Moisture ‑ copper is less available in waterlogged soil.
* Zinc ‑ excess zinc reduces copper availability.
* Nitrogen ‑ excess nitrogen can prevent copper from being transported around plants and nitrogen deficiency can reduce the uptake of copper.
* Phosphorus ‑ excess phosphorus can reduce copper uptake.

Ideally, for healthy and productive soil, the concentration of copper should be 2‑50 mg/kg. it would be a good idea to investigate the reasons behind high levels if a copper concentration of greater than 6000 mg/kg is detected in your soil.

**Copper Deficiency**

Copper deficiency is more likely to be seen in plants grown in sandy, alkaline soils.

**Symptoms of Copper Deficiency**

Copper deficiency in plants can result in poor growth, delayed flowering and sterility. As a result of the latter, seed saved from copper deficient plants, even plants that recover from a copper deficiency, will often have a poor germination rate. Uniform [chlorosis](https://plantprobs.net/plant/nutrientImbalances/definitions.html) may also occur on new leaves and leaves may curl under and/or wilt. In some cases, [interveinal chlorosis](https://plantprobs.net/plant/nutrientImbalances/definitions.html) may be the initial symptom with [chlorosis](https://plantprobs.net/plant/nutrientImbalances/definitions.html) extending to the veins after prolonged deficiency.

**Treating Copper Deficiency**

The first step to treating copper deficiency is to check and if necessary adjust the pH of the soil. Copper is most easily absorbed by plants if the soil pH is between 5.5 and 6.5 though adequate uptake should still occur provided the pH is between 4.5 and 7.5 and the soil isn't waterlogged. If the soil is boggy, take steps to improve the drainage of the soil by adding organic matter and aerating the soil with a fork. Alternatively, a quick solution is to transplant the affected plant to a raised bed or other better drained site.

While organic matter can reduce the uptake of copper, it is still important to have enough organic matter in the soil for all its other benefits so don't be tempted to stop adding organic matter to the soil. At the same time, digging too close to plants can disrupt root development (among other things) and this can severely limit a plant's ability to absorb copper and other nutrients so organic matter is best added as mulch rather than being dug into the soil.

If symptoms persist after the above steps, it would be a good idea to have your soil copper, [nitrogen](https://plantprobs.net/plant/nutrientImbalances/nitrogen.html), [phosphorus](https://plantprobs.net/plant/nutrientImbalances/phosphorus.html) and [zinc](https://plantprobs.net/plant/nutrientImbalances/zinc.html) levels tested. If any of these elements are not present at appropriate levels, then you may consider taking more direct action to solve the problem ‑ clicking on the other elements ([nitrogen](https://plantprobs.net/plant/nutrientImbalances/nitrogen.html), [phosphorus](https://plantprobs.net/plant/nutrientImbalances/phosphorus.html) or [zinc](https://plantprobs.net/plant/nutrientImbalances/zinc.html)) will take you to that element's page of this website. To add more copper to your soil, copper sulfate (a foliar spray and/or a soil amendment) is probably the best choice.

If any of your plants are also suffering from fungal infections, a copper based fungicide may be an effective treatment so decide whether you will try such a treatment before amending the soil as copper fungicide treatment will likely increase your soil's copper concentration.

**Copper Toxicity**

Copper toxicity in plants can inhibit iron uptake and can also stunt growth. Excess soil copper can inhibit seed germination. High soil copper levels can occur as a result of excessive use of copper containing fungicides and industrial activity (such as mining).

When reviewing the results of a soil copper test, be alert for copper levels that are close to the maximum recommended value as well as excesses. High but not excessive levels are significant because if any of your fruit trees, roses or other plants that are susceptible to fungal diseases develop such diseases, you may need to resort to a copper spray (there are some that are suitable for organic gardens if you garden that way). If so, you'll need to be especially careful during application to ensure you don't end up increasing your soil's copper level.

If you find excessive levels of copper in your soil, ensure your soil has enough phosphorus and zinc, that the pH isn't too low (too acidic) and add plenty of organic matter on a regular basis. You'll also need to be careful not to add any additional copper when fertilising or treating diseases. Microorganisms can be affected by high levels of copper so care should be taken to promote their growth (providing organic matter is a good start but you should also reduce digging as this disrupts the growth of microorganisms).

**Iron**

Iron is the fourth most abundant element found in soil though it is largely present in forms that cannot be taken up by plants. Iron, in small amounts, is essential for healthy plant growth and is classed as a [micronutrient](https://plantprobs.net/plant/nutrientImbalances/definitions.html). It is important for the development and function of chlorophyll and a range of enzymes and proteins. It also plays a role in respiration, nitrogen fixation, energy transfer and metabolism. As with other nutrients, plants can have too much iron but this primarily affects the uptake of other nutrients rather than producing direct toxicity symptoms.

The amount of iron and its availability in soil is influenced by the following:

* pH ‑ high pH reduces iron availability, low pH increases it
* Organic matter ‑ organic matter provides iron and makes it more readily available
* Moisture ‑ excess water in the soil, particularly in acidic soils, increases iron availability even to the point of toxicity
* Aeration and compaction ‑ compacted and/or poorly aerated soils have an increased iron availability, particularly if the soil is acidic
* Phosphorus ‑ excess phosphorus inhibits the uptake of iron
* Nitrogen ‑ certain forms of nitrogen can reduce iron uptake
* Zinc ‑ zinc deficiency can increase the uptake of iron in some plants, excess zinc decreases iron uptake
* Manganese ‑ excess manganese inhibits the uptake of iron
* Potassium ‑ potassium deficiency may increase iron uptake
* Molybdenum ‑ excess molybdenum can reduce iron uptake especially in alkaline soils
* Nickel ‑ excess nickel can reduce the uptake of iron
* Bicarbonate ‑ bicarbonate in the soil can reduce iron uptake

**Ideal Soil Iron Levels**

Soil is typically between 1% and 5% iron but because most of this iron is unavailable, it is difficult to set an ideal amount for soil. Some estimates suggest that soil should have at least 0.001 g of iron in every 100 g of soil (or 10 mg/kg).[[1]](https://plantprobs.net/plant/nutrientImbalances/iron.html#ref1)

**Iron Deficiency**

Iron deficiency is most likely to occur in plants when the soil is alkaline or when the level of phosphorus, nitrogen, zinc, manganese or molybdenum in the soil is high. Heavy metal contamination can also lead to iron deficiency.

**Symptoms of Iron Deficiency**

[Interveinal chlorosis](https://plantprobs.net/plant/nutrientImbalances/definitions.html) is the most common symptom of iron deficiency. Symptoms are usually seen on young leaves first.

**Treating Iron Deficiency**

It is particularly important to treat iron deficiencies because some plants respond to a lack of iron by making the soil directly around their roots more acidic and this can cause imbalances in other plant nutrients.[[2]](https://plantprobs.net/plant/nutrientImbalances/iron.html#ref2) Treating iron deficiency is however, quite complicated. Adding phosphorus, nitrogen, zinc, manganese and molybdenum should be avoided unless one of these elements is deficient in the soil. Plenty of organic matter should be added to the soil.

Soil pH should be tested and amended if required. Iron is most available to plants when the pH of the soil is 7 or lower though most plants should be able to uptake sufficient iron if the pH of the soil is 8 or lower provided other essential elements are well balanced. If the soil is too alkaline, it is especially important to lower the soil pH if you're growing acid loving plants.

Apart from these key things, it's also important to ensure the soil doesn't dry out and a thick layer of organic mulch will assist with this as well as adding more organic matter to the soil.

If symptoms persist after taking the above actions, it would be a good idea to have your soil tested to determine the amount iron in the soil (in a form that can be used by plants). You should also test the amount of [phosphorus](https://plantprobs.net/plant/nutrientImbalances/phosphorus.html), [nitrogen](https://plantprobs.net/plant/nutrientImbalances/nitrogen.html), [nickel](https://plantprobs.net/plant/nutrientImbalances/nickel.html), [zinc](https://plantprobs.net/plant/nutrientImbalances/zinc.html), [molybdenum](https://plantprobs.net/plant/nutrientImbalances/molybdenum.html) and bicarbonate in the soil. If any of the later are present in toxic quantities in the soil you should do what you can to reduce the excess levels. If bicarbonate is in the soil, it would be a good idea to test the water you use for irrigation to ensure that isn't the source of the contamination. If not, it would be a good idea to seek expert advice on how to treat the problem because there are a wide range of factors unique to your soil conditions, which can affect the level of bicarbonate in the soil.

When all of these issues are either excluded or remedied then you may consider adding iron to the soil. Organic sources of iron include some iron chelates (check the label to see if it's certified as suitable to use on an organic property) and synthetic sources include ferrous and ferric sulfate.

**Iron Toxicity**

Iron toxicity is most commonly associated with highly acidic soil though symptoms of iron toxicity are mostly symptoms of other nutrient deficiencies. For this reason, if you notice such symptoms and can't seem to remedy the issue by ensuring the soil has a neutral pH and then following the recommendations on the relevant page, it's a good idea to order both soil and plant tissue tests to see whether it's actually an excess of iron that's causing the problem.

**Symptoms of Iron Toxicity**

Symptoms of true iron toxicity usually include bronzing of the leaves and possibly also the formation of brown spots on leaves.

**Treating Iron Toxicity**

If excess iron is indeed the problem, treatment can be just as complicated as the treatment of iron deficiency. Firstly, the soil pH should be checked an amended if required ‑ aim for a neutral pH unless the plant you're growing requires acidic (or alkaline) soil. Drainage should also be improved if the soil is waterlogged and the soil should be aerated if it is compacted. Also, be careful to only water when necessary.

If a soil test reveals that the soil is deficient in any element, this should be treated next. Pay particular attention to zinc or potassium deficiencies as these can be the cause of iron toxicity or could make it worse.

If nutrient deficiency symptoms and/or iron toxicity symptoms are still visible on plants months after these treatments, you may need to boost the levels of the nutrients in the soil a little to overcome the effects of a severe excess of iron. Always be careful to do this gradually and in consultation with both soil and tissue testing in order to prevent toxicity of any other element.

I would also recommend that you investigate the source of excess available iron in the soil. It may be that the soil is being contaminated by an external source ‑ contaminated bore water or runoff from nearby properties for instance.

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**Lead**

Lead is a naturally occurring heavy metal. It is however, toxic to plants and humans.

**Lead in Soil**

Many houses today were once painted with paints that contained lead ‑ unless the paint was removed, that paint will still be there under layers of newer paint. Lead is also used in a number of alloys, flashing, solder and some batteries. Lead is released during combustion of fossil fuels and many manufacturing process produce or release lead. Soil may become contaminated with lead if it is exposed to any of these substances or processes or if water runoff from such substances infiltrates the soil. Mining activity may also lead to lead contamination. Note that soil within a metre of houses and garages is often contaminated with paint chips that contain lead. Lead in soil does not biodegrade nor does it leach easily so even structures that have had all lead paint removed may have lead contaminated soil in this area as a result of previous exposure.

**Lead in Humans**

Lead is particularly dangerous for children. Even low levels of lead in the blood of a child can irreversibly affect IQ and attention.[[1]](https://plantprobs.net/plant/nutrientImbalances/lead.html#ref1) Lead can cross the placenta so pregnant women who are exposed to lead can pass that lead to their unborn child where it can damage the baby's nervous system. Lead exposure can also cause miscarriage, stillbirths and infertility in both men and women. Soil clings to fingers, toys and other objects that children normally put into their mouths. If that soil is contaminated with lead, children will absorb the lead. Lead contaminated soil should thus be covered to prevent access ‑ mulch, grass and concrete are all effective barriers.[[2]](https://plantprobs.net/plant/nutrientImbalances/lead.html#ref2) If contaminated soil cannot be covered, children's access should be restricted.

Lead is not just dangerous for children however. It can be stored in bones, blood and a variety of tissues (regardless of a person's age at exposure) whereby it can produce a wide range of effects. Large, short term doses of lead can cause, in children and adults, abdominal pain, constipation, fatigue, weakness, headaches, irritability, loss of appetite, memory loss, pain or tingling in the hands and feet, anaemia, kidney and brain damage and even death. Long term exposure can cause similar symptoms along with depression and reduced fertility. Lead is also a probable carcinogen.[[3]](https://plantprobs.net/plant/nutrientImbalances/lead.html#ref3) Adults are less likely to ingest contaminated soil but they may inhale lead or ingest lead contaminated food. Anyone concerned about lead exposure can request blood tests for lead.

**Lead in Food and Plants**

Food can become contaminated with lead if it is grown in lead contaminated soil. Lead can remain in the soil for up to 2000 years[[4]](https://plantprobs.net/plant/nutrientImbalances/lead.html#ref4) and it is toxic to plants in a variety of ways. It strongly inhibits seed germination, root and plant growth, seedling development, transpiration and chlorophyll production and it negatively affects water and protein content.[[5]](https://plantprobs.net/plant/nutrientImbalances/lead.html#ref5) Lead taken up by plants concentrates mostly in the roots of the plant[[4]](https://plantprobs.net/plant/nutrientImbalances/lead.html#ref4) but its affects are noticeable throughout the plant, especially since it also impedes the uptake of essential nutrients such as magnesium and iron[[5]](https://plantprobs.net/plant/nutrientImbalances/lead.html#ref5). Plants can act to reduce their uptake of lead and by adding calcium and phosphorus to the soil, you can also reduce the amount of lead taken up by plants.

In addition to direct toxic effects on plants, lead can indirectly affect a variety of plants. At concentrations of 10000‑40000 mg/kg, lead can kill soil bacteria and fungi.[[4]](https://plantprobs.net/plant/nutrientImbalances/lead.html#ref4) This in turn negatively affects the growth of many plants and inhibits organic matter decomposition (which prevents nutrient recycling and thus plant growth). At concentrations between 500 and 1000 mg/kg, lead can bias the types of microorganisms present.[[4]](https://plantprobs.net/plant/nutrientImbalances/lead.html#ref4) This can affect the types of plants that grow best in a particular area.

**How Much Lead is Safe?**

Depending on where you live, there may be a number of guidelines for soil lead levels that are relevant to you. If you grow edibles, maximum recommended levels for agricultural soil will be relevant. Guidelines for soil in residential areas may also be available and this is particularly useful for those who don't garden but may be exposed to lead in the soil in other ways (anyone can breath in dust and children frequently hands and toys in their mouths). If you garden at a community garden, you might find guidelines for lead in the soil surrounding public infrastructure such as schools and child care centres. Note that some of these guidelines may not specify unsafe levels; they may instead specify levels that should instigate further investigation. As such, ensure you read your guidelines carefully. I can't provide values for every country here (note that many soil testing companies will provide information about ideal or acceptable levels when they give you your results) but the following values are used in Australia and might be useful to you as a guide:

* The maximum recommended soil lead value for agricultural soil is 35 mg of lead per kg of soil.[[6]](https://plantprobs.net/plant/nutrientImbalances/lead.html#ref6)
* If soil lead levels are over 300 mg/kg the Australian environmental protection measure for residential, primary school and child care facilities recommends further investigation.[[7]](https://plantprobs.net/plant/nutrientImbalances/lead.html#ref7)

Environmental protection agencies in California, Canada, Norway and the United States publish guidelines for lead in soil as well: 80 mg/kg, 140 mg/kg, 90 mg/kg and 400 mg/kg respectively.

**Dealing with Excess Lead in the Soil**

If you have concerns about relatively minor contamination of soil with lead, there are some strategies you can use to reduce the chance of ingesting and inhaling soil. For instance, you can ensure all soil is either covered with plants, or if that's not possible, you could use mulch or even pave the area (what ever works best for the intended use of your soil). This is especially useful for preventing children from eating soil as they often like to play in dirt. You should also ensure that everyone in your family (or all members of your community garden) washes their hands thoroughly after gardening or touching the soil for any other reason.

Also, when it comes to growing edible plants in an area with contaminated soil it is important to note that not all plants absorb lead to the same extent. Leafy greens such as lettuce and silverbeet and root crops such as beetroot and carrots uptake the most lead. Bulbous and tuberous plants such as potatoes, onions and garlic uptake the next highest amount of lead.[[2]](https://plantprobs.net/plant/nutrientImbalances/lead.html#ref2) Both these classes of produce should be grown in raised beds containing clean soil if you have concerns about your ground soil (make sure you test any purchased soil or ask to see an analysis of it before you buy). The beds need to be deep enough to cover the majority of root growth (to ensure significant root mass doesn't penetrate the contaminated soil). Deep rooted green manures should not be used to mulch the soil as these may concentrate lead and then contaminate the clean soil. Corn, cauliflower, asparagus, celery and berries uptake only low levels of lead. Most other fruiting plants such as beans, tomatoes, melons and fruit trees uptake very low levels of lead.[[2]](https://plantprobs.net/plant/nutrientImbalances/lead.html#ref2) If your ground soil doesn't contain too much lead, it may be safe to grow these plants in the ground. If concerns remain about the safety of this produce, tissue tests can be performed on the fruit to determine whether any lead (or unsafe levels of lead) is present in the fruit.

If a soil test reveals very high levels of lead, I would recommend that you seek expert advice on your situation. You may need to replace the soil in your garden in extreme circumstances.

**Bioremediation of Soil Contaminated with Lead**

Other than being careful not to exposure yourself to lead, you may also be able to deal with lead in soil by removing it. Some plants absorb a lot of lead and it might be possible to use them to assist you. Vetiver grass and *Thlaspi caerulescens* both accumulate lead and distribute it to their foliage.[[8]](https://plantprobs.net/plant/nutrientImbalances/lead.html#ref8) Such plants could be grown in contaminated soil and the foliage regularly pruned and destroyed off site in an attempt to remove the lead. In the long term, this kind of bioremediation may be useful but it is a slow process and it will not be successful if the land can be re‑contaminated by water leached from uphill contaminated soil or from an active mine or smelter.

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**Magnesium**

Magnesium is essential for healthy plants and is deemed a [secondary macronutrient](https://plantprobs.net/plant/nutrientImbalances/definitions.html). It is a constituent of chlorophyll so is required for photosynthesis. It is also a component of many plant enzymes and aids in their function. Magnesium helps plants move phosphorus to where it is needed and to use iron. It is important for the uptake of a variety of nutrients and for nitrogen fixation by bacteria associated with with legumes.

The availability of magnesium in the soil is affected by:

* pH - low soil pH reduces the availability of magnesium, high pH increases it
* Manganese - excess manganese decreases magnesium uptake
* Cation exchange capacity - soil that is high in organic matter and clay will maintain higher levels of magnesium (such soil will absorb magnesium easily and will prevent it from leaching) though if the soil contains little magnesium, it will be harder for plants to take it up
* Other [cations](https://plantprobs.net/plant/nutrientImbalances/definitions.html) - excess levels of other [cations](https://plantprobs.net/plant/nutrientImbalances/definitions.html), potassium in particular, will prevent the uptake of magnesium
* Soil temperature - low soil temperature reduces magnesium uptake

Ideally, for healthy and productive soil you should aim for a magnesium concentration of at least 1.6 meq/100g (milliequivalents - this is a special term used to describe the amount of some elements in soil).

**Magnesium Deficiency**

Magnesium deficiency is most likely to occur in plants grown in acid and/or cold soil. The presence of excess levels of some other nutrients will also increase the chance of magnesium deficiency. In costal sites, areas where the water table has been disturbed and properties where bore water is used, high levels of sodium may also cause symptoms of magnesium deficiency

**Symptoms of Magnesium Deficiency**

The most obvious symptom of magnesium deficiency in plants is [interveinal chlorosis](https://plantprobs.net/plant/nutrientImbalances/definitions.html) in older leaves. [Necrotic](https://plantprobs.net/plant/nutrientImbalances/definitions.html) spots may also develop on older leaves. In some plants, manganese deficiency may result in leaves that curl over (rather than under).

**Treating Magnesium Deficiency**

If magnesium deficiencies are detected or suspected in one or more plants, the first step to treating the problem is to check that the pH of the soil is appropriate. Magnesium is in a form most easily uptaken by plants when the soil pH is between 7.5 and 9 but provided the pH is between 6.5 and 9.5 most plants should be able to uptake adequate amounts (as long as the soil contains sufficient magnesium). Plants that require a pH outside this range (such as azaleas and blueberries) may require more magnesium the soil to compensate for reduced availability.

If symptoms of deficiency appear early in the season, cloches can be used to raise the soil temperature. If fertilisers high in other are being used these should also be substituted for fertilisers low in [cations](https://plantprobs.net/plant/nutrientImbalances/definitions.html).

If these measures do not completely resolve the problem and a soil test confirms that the soil is deficiency in magnesium, a magnesium containing fertiliser can be applied. Most limes contain magnesium and are useful if the soil is too acidic though dolomite contains more magnesium than standard lime. Epsom salts are also a cheap and readily available solution that can be used regardless of soil pH. Rock dust contains a range of nutrients including magnesium.

**Magnesium Toxicity**

Magnesium toxicity is rare. Deficiencies in other [cations](https://plantprobs.net/plant/nutrientImbalances/definitions.html), such as potassium and calcium, are likely to arise before magnesium toxicity itself becomes a problem. If excess magnesium is causing other deficiencies, adding some of the appropriate element will usually be an appropriate shot term fix. For a long term fix, you should investigate the cause of the excess magnesium and aim to fix the problem.

**Manganese**

Manganese is a plant [micronutrient](https://plantprobs.net/plant/nutrientImbalances/definitions.html). It fulfils a number of roles and is used in photosynthesis (manganese is important for a number of aspects of photosynthesis), synthesis of chlorophyll and nitrogen absorption as well as the synthesis of riboflavin, ascorbic acid and carotene.

A wide variety of factors can affect manganese availability including:

* pH ‑ high pH reduces availability and low pH can increase availability to the point of toxicity if there is an excess in the soil
* Organic matter ‑ the more organic matter in the soil the lower the availability of manganese
* Moisture ‑ changes in soil moisture can convert available forms of manganese to unavailable forms and vice versa and rapid changes in soil moisture can cause deficiencies and toxicities
* Iron ‑ excess iron reduces manganese uptake by plants
* Silicon ‑ addition of silicon can reduce the likelihood of symptoms of toxicity in plants that uptake excess levels of manganese
* Nitrogen ‑ low nitrogen levels can reduce manganese uptake by plants
* Anions (negatively charged ions such as nitrate, phosphate, sulfate) ‑ excess anions can increase the uptake of manganese

Ideally, for healthy and productive soil the concentration of manganese should be 10‑50 mg/kg. it would be worth conducting further investigations if your soil contains more than 3800 mg of manganese for every kg of soil.

**Manganese Deficiency**

Manganese deficiency is most common on alkaline and poorly drained soils as well as those high in available iron.

**Symptoms of Manganese Deficiency**

Symptoms of manganese deficiency include [interveinal chlorosis](https://plantprobs.net/plant/nutrientImbalances/definitions.html) of new leaves, [necrotic](https://plantprobs.net/plant/nutrientImbalances/definitions.html) spots and sometimes, small and/or irregularly shaped leaves.

**Treating Manganese Deficiency**

In the event that you detect a manganese deficiency in your plants, a number of steps can be taken. Firstly, check that the soil pH is close to neutral. Manganese is most readily available to plants when the soil pH is between 5 and 7 though most plants will be able to uptake sufficient manganese if the soil pH is between 4.5 and 7.5 provided that there aren't any other problems with the soil. If the pH is too high, use an acidifying agent, such as sulfur, to lower the pH but just ensure that the pH doesn't drop so low as to result in other nutrient imbalances.

If you have doubts about the amount of nitrogen your plants are getting, adding nitrogen can also boost the uptake of manganese. You can do this by growing legumes near your plants or if a soil test reveals a nitrogen deficiency, you can add a nitrogen containing fertiliser (a general fertiliser will also increase the concentration of anions in the soil and further improve uptake). If there is an excess of available iron in the soil, check that irrigation water or run off from a nearby property isn't the cause.

If a soil test reveals that the concentration of manganese in the soil is below 10 mg/kg, a manganese fertiliser may be applied sparingly. Manganese chelate can be an organic‑friendly option (check the label) or you may chose to use a synthetic fertiliser such as manganese sulfate or manganese oxide.

**Manganese Toxicity**

Manganese toxicity is more common on very acidic soil. It can be toxic in it's own right but excess manganese can also cause iron deficiency.

**Symptoms of Manganese Toxicity**

Manganese toxicity may present as distorted leaves with dark specks. In severe cases, leaves will start to die from the outer edges in.

**Treating Manganese Toxicity**

Adding organic matter to the soil may help prevent symptoms of toxicity as will maintaining a neutral soil pH. If the pH of your soil is below 5, lime can be added to neutralise it. Any supplemental fertiliser applied to the soil should be free of manganese and low in nitrogen. Soil moisture should be kept as constant as possible to prevent fluctuations in manganese levels.

**Molybdenum**

Molybdenum is a plant [micronutrient](https://plantprobs.net/plant/nutrientImbalances/definitions.html). Molybdenum is only required in very small amounts but it is important for nitrogen metabolism; without molybdenum, plants may be able to take up nitrogen but if it's in the form of a nitrate (NO3‑) they can't process it and use it for it's intended purpose (to make amino acids and proteins for instance). Legumes may also have difficulty 'fixing' nitrogen (more accurately, the legumes have trouble using nitrogen and the nitrogen fixing bacteria they associate with have trouble converting atmospheric nitrogen to a form that the plant can use). Molybdenum also plays an essential role in the use of phosphorus within plants. Without molybdenum, plants may be able to take up inorganic phosphorus but they will struggle to convert that phosphorus into an organic form that they can use.

Factors that affect the availability of molybdenum include:

* Excess water ‑ high rainfall and frequent irrigation can wash molybdenum from the soil.
* Soil pH ‑ molybdenum is more easily uptaken by plants when the pH of the soil is high and less easily uptaken when the pH is low.
* Nitrogen ‑ the type of nitrogen in the soil and in any applied fertiliser can affect the amount of molybdenum that is required by plants. When more of the nitrogen is in the form of amonium (NH 4+), less molybdenum is required. When more more of the nitrogen is in the form of nitrate (NO3‑), more molybdenum is required.

Ideally, for healthy and productive soil the concentration of molybdenum in the soil should be at least 2 mg/kg.

**Molybdenum Deficiency**

Acidic soils and those comprised primarily of sandstone are more likely to be deficient in molybdenum.

**Symptoms of Molybdenum Deficiency**

Molybdenum deficiency stunts plant growth and plants may appear to have a nitrogen deficiency (because they're unable to use nitrogen properly). Leaves may also exhibit spots of [chlorosis](https://plantprobs.net/plant/nutrientImbalances/definitions.html) between the veins and along the edges. Eventually, the edges of leaves may turn brown and die though this only occurs in some plant species. Symptoms appear in older leaves first. The pollen of molybdenum deficient plants will usually be less viable than that of healthy plants so grain and fruit production is often reduced. Molybdenum deficiency is usually seen first in cauliflower as it has a high molybdenum requirement. Affected cauliflower plants will usually have cupped leaves.

**Treating Molybdenum Deficiency**

If your soil isn't neutral then adding lime may improve the uptake of molybdenum by your plants as molybdenum is most available when the pH of the soil is at least 7 though if the pH is at least 6, most plants should be able to uptake enough molybdenum. An increase in organic matter is also useful as it should help prevent molybdenum from being leached from the soil.

If soil tests reveal that the soil contains too little molybdenum, then you can use a molybdenum fertiliser to increase the level. Seaweed extracts may contain small amounts of molybdenum and are useful if you garden organically. Otherwise, sodium molybdate and ammonium molybdate are useful synthetic fertilisers that contain molybdenum. As sodium can be harmful to plants, I would use ammonium molybdate unless the soil contains large amounts of nitrogen.

**Molybdenum Toxicity**

Molybdenum toxicity is rare and it is of greater concern to the animals (generally ruminants) that eat plants containing excess molybdenum than it is to the plants themselves. Symptoms of toxicity are similar to deficiency and the more obvious symptoms of toxicity are actually symptoms of deficiency of other nutrients because high levels of molybdenum can reduce the absorption of other nutrients ‑ copper in particular. If molybdenum toxicity is ever suspected, an application of sulfur can reduce molybdenum uptake until the soil level drops and especially if the pH of the soil is greater than 7; care must be taken though to prevent other nutrient imbalances. In such circumstances, molybdenum containing fertilisers should not be used.

# Nickel

Nickel is a plant [micronutrient](https://plantprobs.net/plant/nutrientImbalances/definitions.html). It contributes to nitrogen fixation and the metabolism of urea (a nitrogen containing compound) and is important for seed germination. Nickel is also important for bacteria and fungi, which are both important for good plant growth.

Ideally, for healthy and productive soil the concentration of 1‑20 mg/kg. It would be a good idea to conduct further investigations if the concentration of nickel in your soil exceeds 400 mg/kg.

## Nickel Deficiency

It was only fairly recently that nickel was recognised as a [micronutrient](https://plantprobs.net/plant/nutrientImbalances/definitions.html) in plants so not a lot is known about symptoms of deficiency.

It does appear though that seeds of nickel deficient plants are often unviable (won't germinate and grow into healthy plants) and that the yield of many crops is reduced. Plants may also show symptoms of if they have a nickel deficiency and in some cases, [chlorosis](https://plantprobs.net/plant/nutrientImbalances/definitions.html) of new leaves may occur.

If a soil test reveals that your soil is nickel deficient you should ensure your soil's pH is around 7 (or an appropriate value for plants that require a different pH such as acid loving plants like blueberries and azaleas) and that the soil contains plenty of organic matter. Once you have done this, you can apply a nickel containing fertiliser. In most areas, you're more likely to find nickel in a general trace element fertiliser than a fertiliser designed specifically to increase soil nickel levels but a custom fertiliser provider should be able to provide a suitable product if your soil is severely deficient in nickel. Whatever fertiliser you choose, ensure you follow the directions carefully so that you don't accidentally add too much.

## Nickel Toxicity

Excess nickel can impede the uptake of other essential nutrients especially iron. It can also inhibit seed germination as well as shoot and root growth. Photosynthesis is impeded by excessive concentrations of nickel and flowers are often deformed under these conditions. Affected leaves may show signs of [chlorosis](https://plantprobs.net/plant/nutrientImbalances/definitions.html) and/or [necrosis](https://plantprobs.net/plant/nutrientImbalances/definitions.html) but this is not always the case.

If your plants are showing symptoms of nickel toxicity, first check that the pH of your soil is appropriate for your plants and if it's not, apply sulfur or lime to lower or raise the pH as appropriate. If toxicity appears to be primarily due to a deficiency in another element (a tissue test combined with a soil test will show this if visual symptoms are not sufficient for diagnosis), the soil should be supplemented with that element. If soil tests reveal excess nickel add lots of organic matter as this can help reduce the amount of nickel being taken up by plants until soil levels lower. Whenever excess nickel is detected in plants or soil, only low nickel fertilisers should be used. It's also a good idea to check that irrigation water doesn't contain high levels of nickel (if in doubt, send some water samples away for heavy metal testing).

**Nitrogen**

Nitrogen is one of the primary nutrients required by plants and is thus termed a [primary macronutrient](https://plantprobs.net/plant/nutrientImbalances/definitions.html). Plants need nitrogen to produce DNA, proteins and chlorophyll; all of which are vital to plant growth and indeed, the life of plants. Some plants, often referred to as nitrogen fixers, can form a beneficial association with nitrogen fixing bacteria. These bacteria can take nitrogen from the air and turn it into a form that plants can use so they don't have to rely on the nitrogen that's already in the soil. In return, plants provide sugars for the bacteria to feed on. Legumes are the most well known class of plant that can form this association with nitrogen fixing bacteria.

Factors that affect the nitrogen availability include:

* Moisture - nitrogen is easily washed from the soil if there is too much water running through it.
* Organic matter - all organic matter releases nitrogen when it breaks down; green (fresh) organic matter contains most if not all of the nitrogen required by organisms to break it down but brown (dry) organic matter usually requires extra nitrogen for this process so initially sucks nitrogen from the soil and away from plants.
* Presence of legumes - legumes associate with nitrogen fixing bacteria allowing them to obtain most of the nitrogen they require from the atmosphere and so the nitrogen in any given patch of soil can support more plants if legumes are grown there than if they are not.

**Nitrogen Deficiency**

Nitrogen deficiency is most likely to occur in high rainfall areas, if the soil is sandy and doesn't contain much organic matter or when soil is poorly managed such as when crops are frequently harvested without any organic matter being returned to the soil to compensate for what is removed. Having said that, some crops and ornamentals have a very high nitrogen requirement (these plants are often referred to as hungry plants) and may suffer from nitrogen deficiency despite good soil management practices. In such situations, you may need to provide supplemental nitrogen or space plants further apart than their size would indicate. If you chose to do the later, you can intersperse plants with other species that have a low nitrogen requirement.

**Symptoms of Nitrogen Deficiency**

The most obvious symptom of nitrogen deficiency is of older leaves. Nitrogen deficient plants also grow more slowly and are usually stunted. Many plant species will mature earlier than normal if they don't have enough nitrogen and will produce a lower yield (of flowers, fruit, seeds or foliage). Plant yields are also often of reduced quality. In very severe cases, leaves of nitrogen deficient plants will begin to die but in most cases, gardeners and farmers should detect the deficiency before it becomes that bad.

**Treating Nitrogen Deficiency**

Always check that the soil pH is appropriate for your plant before doing anything else. Nitrogen starts to become less easily uptaken by plants if the soil pH is below 6 or greater than 8. If the pH isn't between 5.5 and 8.5 then this is likely the primary cause of the symptoms your plant is displaying (except for certain special plants that like extreme pHs - eg blueberries and azaleas which like very acidic soils). Also make sure that your plant has adequate water.

If there are no obvious reasons why your plant isn't able to uptake enough nitrogen then nitrogen deficiency in the soil may be suspected. In this case, the first treatment should be the addition of compost, other green organic matter and a layer of mulch. In particular, legume foliage and roots contains good levels of nitrogen. You may also apply a balanced fertiliser such as blood and bone or fish meal or a generic synthetic fertiliser. These will release a variety of nutrients slowly and will help to correct the problem with little risk that you will accidentally throw out the balance of another nutrient. An application of liquid fish emulsion is a good choice if your plants are severely deficient and so you need to boost nitrogen levels quickly.

If soil tests confirm that nitrogen deficiency is indeed the culprit and is the only nutrient problem, you may consider using a high nitrogen fertiliser. Aged chicken manure is high in nitrogen (in fact all poultry manures are - they need to be aged or composted to prevent them from burning your plants) as is dried blood or blood meal or your can apply a synthetic urea, ammonium or nitrate based fertiliser provided you strictly follow the instructions.

**Nitrogen Toxicity**

Nitrogen toxicity can occur through a number of mechanisms but is usually a result of the application of excessive amounts of fertiliser. Toxicity symptoms may be a result of plants having uptaken too much nitrogen in any form or they may result from excess levels of ammonium which is a nitrogen containing ion (NH4+).

**Symptoms of Nitrogen Toxicity**

Plants suffering from nitrogen toxicity may be stunted but are more often very tall and spindly. Foliage will be a deep green colour but plants will be more likely to succumb to diseases and pest attacks and will be more susceptible to frost damage. Often if a plant fails to flower and/or fruit, it is because it has absorbed too much nitrogen.

**Treating Nitrogen Toxicity**

Adding lots of brown organic matter (such as autumn leaves and straw - these things have a high carbon it nitrogen ratio) to the soil (by digging it into the soil and by adding it as mulch) can alleviate symptoms of nitrogen toxicity because lots of nitrogen is required by the organisms that break down high carbon organic matter. Nitrogen is relatively easily flushed from the soil so frequent watering will help remove any excess. Be aware though that this will flush out other nutrients too and too much water can promote fungal diseases and cause roots to rot. Provided you don't go overboard, applications of potassium can help improve flowering and fruit set and potassium and dilute seaweed solution can both increase a plant's resistance to pest (including disease) and frost damage.

If you do nothing, high levels of soil nitrogen as a result of excessive fertiliser application will usually drop down to healthy levels in a few months but your plants may not recover if symptoms are severe.

**Symptoms of Ammonium Toxicity**

While you won't see this unless you did your plants up, the roots of plants that have been exposed to too much ammonium will turn brown and the tips of the roots will usually die. The result of this is that plant growth is decreased. Plants will often also develop spots on the stems and leaves. The new leaves of some plant species may be stunted and yellow.

**Treating Ammonium Toxicity**

Once again, if you do nothing, the amount of ammonium in the soil will reduce down to a normal level by itself though plants may not survive if ammonium levels are too high for too long so it is a good idea to take some corrective action if toxicity symptoms are apparent. Ammonium toxicity is more common on acidic soil so make sure the pH is appropriate for your plant. As with 'normal' nitrogen toxicity, adding potassium can help resolve symptoms but be sure you don't increase soil potassium levels above desirable levels (this can cause deficiencies in other nutrients). Again, adding lots of brown organic matter can also help treat ammonium toxicity.

Ammonium toxicity is common in plants grown in soil-less media so be especially careful when adding ammonium to hydroponic systems.

**Phosphorus**

Phosphorus is a [primary macronutrient](https://plantprobs.net/plant/nutrientImbalances/definitions.html) (it's the P in NPK). It is required for plant respiration and photosynthesis as well as cell division and growth (and thus plant growth). It is also vital for the production of fruit and seeds and is an important part of proteins, enzymes and DNA. When plants can uptake sufficient quantities of phosphorus, their roots grow early on and overall plant growth is better in cold temperatures. More flowers and seeds are also produced and fruit and grains mature more quickly. Furthermore, these products tend to be of a higher quality. Adequate phosphorus also ensures that plants use water efficiently. In legumes, phosphorus is important for nodule development and function (which is important for nitrogen fixation).

A wide variety of factors can influence the availability of phosphorus including:

* pH - phosphorus becomes less available when the soil pH increases above 7.5 and when it decreases below 6.5. This is as a result of it binding with calcium and aluminium respectively.
* Compaction - compacted soil makes it difficult for roots to spread quickly in order to obtain phosphorus from new locations.
* Aeration - poorly aerated soil (from compaction and/or poor drainage) reduces oxygen flow to plant roots and this can reduce phosphorus uptake by as much as 50%.
* Moisture - lack of water reduces phosphorus availability and uptake. Too much moisture can reduce the amount of oxygen getting to roots however and this can reduce uptake.
* Soil temperature - cold soil reduces the uptake of phosphorus.
* Cation exchange capacity - the more clay and organic matter in the soil, the more phosphorus it holds. Soils with high cation exchange capacities also tend to hold more water which facilitates the movement of phosphorus to plant roots.
* Organic matter - organic matter supplies phosphorus and can increase the amount of phosphorus that is available to plants.
* Mycorrhizas - fungi can form symbiotic relationships with plants and these are called mycorrhizas. Mycorrhizas can increase the amount of phosphorus uptaken by plants.

Ideally, for healthy and productive soil you should aim for a phosphorus concentration of 20‑100 mg/kg.

**Phosphorus Deficiency**

Plants are most likely to suffer from phosphorus deficiency when they are grown in compacted, poorly aerated soil that is low in organic matter. Symptoms are also more prevalent early in the season when the soil is cold.

**Symptoms of Phosphorus Deficiency**

Phosphorus is a fairly mobile element in plants so deficiency symptoms are more often seen on older leaves (because the phosphorus from old leaves is more easily redirected to new leaves as they're produced). The symptoms of phosphorus deficiency vary widely between species but most plants will show the following symptoms:

* Leaf tips appear burnt
* Sometimes the rest of the leaves will become spotted with [necrotic](https://plantprobs.net/plant/nutrientImbalances/definitions.html) tissue
* Older leaves will turn a darker blue‑green or a reddish‑purple; in some cases they may go yellow first or the leaves may go yellow and drop off
* Plants will be dwarfed or stunted

Some symptoms that are only displayed by certain species include:

* The stems and underside of leaves of some plants such as tomatoes (and other fruiting nightshades), lettuce, corn and brassicas will often turn a purple colour
* In corn, the purple colour usually begins along the margins of the leaves
* Strawberry leaves will turn red or red‑brown, usually from the outside in
* Legumes will often show symptoms of nitrogen deficiency because a lack of phosphorus affects their ability use nitrogen fixing bacteria to produce nitrogen

**Treating Phosphorus Deficiency**

When plants display symptoms phosphorus deficiency, your first steps should be to neutralise the soil pH, loosen and aerate the soil (with a fork) and reduce the amount of digging (to prevent disruptions to mycorrhizas). Aim for a pH if between 6.5 and 7.5 but as long as your soil's pH is between 6 and 8, most plants should be able to uptake sufficient phosphorus provided the soil contains enough. Excess phosphorus may be needed when plants require quite acidic soils however (azaleas and blueberries require acidic soil for instance).

If deficiencies are experienced early in the season, cloches can be used to warm the soil. If you have a large property, you may also consider installing an automatic watering system in order to maintain optimal soil moisture levels.

Regardless of the size of your property you should also add lots of organic matter to your soil. A good, thick application of organic mulch will be useful but initially you may need to dig some organic matter into the soil as well (make that the last time you dig your soil ‑ except when planting or transplanting or when harvesting tubers). In order to prevent future deficiencies, you'll need to continue to add organic matter periodically. Home grown green manures are a good source of organic matter and if you have the space you cal so grow your own straw.

If this doesn't fix the problem and a soil test confirms that a low level of phosphorus in the soil is the culprit, high phosphorus fertiliser can be used to boost levels. Organic fertilisers that contain a decent amount of phosphorus include bone meal and animal manures; poultry manure in particular. Rock dust and rock phosphate are also good sources of phosphorus (rock dust contains a variety of other minerals as well). There are a variety of high phosphorus inorganic fertilisers including superphosphate. Be aware that many of these contain however and this toxic heavy metal can be difficult to remove from the soil once it's been added.

**Phosphorus Toxicity**

Excess soil phosphorous is concerning because it can easily flow into waterways when it rains or if excessive irrigation water runs off a property (excess phosphorus causes algal blooms and excessive vegetative growth when it enters waterways). Excessive levels of soil phosphorus are not particularly detrimental to plant health however, though they can impede the uptake of iron and zinc. As a result, symptoms of phosphorus toxicity when they do occur are actually symptoms of iron and/or zinc deficiency.

It is difficult to remove phosphorus from the soil but excess levels can be remediated by using low phosphorus (or phosphorus free) fertilisers until the levels drop (as a result of crop harvest and leaching). It is also a good idea to cease using phosphorus accumulating plants as mulch.

If your garden is watered with grey water, ensure that all detergents used around the house are low in phosphorus.

**Potassium**

Potassium, the K in NPK, is essential for healthy plant growth and is deemed a . It plays roles in photosynthesis and plant food formation as well as transport and storage of plant food. As a result of this, it is also important for nitrogen fixation in legumes because nitrogen fixing bacteria rely on food from their associated plant in order to convert nitrogen from the atmosphere into nitrogen that plants can use. In conjunction with calcium and boron, it is also very important for the development of plant cell walls so among other things, it helps plants resist frost and cold damage. It also controls a plant's ability to cope with drought and helps plants combat disease and insect damage. Many gardeners know potassium as potash but this term more accurately describes potassium chloride. This is an important distinction as gardeners who add potash to their soil to boost potassium levels may end up increasing soil chloride levels enough to cause toxicity. Potassium is a component of wood ash and this is where the term potash comes from.

A wide variety of factors affect potassium availability including:

* Cation exchange capacity - high levels of clay and organic matter in the soil prevent leaching of potassium though if soil contains little potassium, it also prevents plants from taking it up.
* Other [cations](https://plantprobs.net/plant/nutrientImbalances/definitions.html) - a large excess of other [cations](https://plantprobs.net/plant/nutrientImbalances/definitions.html) in the soil prevents plants from taking up potassium. This is especially true of sodium.
* Moisture - a lack of water prevents potassium uptake.
* pH - low soil pH reduces the availability of potassium.
* Temperature - potassium is less available in cold soils.
* Soil drainage, compaction and aeration - potassium becomes less available as the soil becomes compacted, water logged and poorly aerated.

Ideally, for healthy and productive soil you should aim for a potassium concentration of at least 0.5 meq/100g (milliequivalents - this is a special term used to describe the amount of some elements in soil).

**Potassium Deficiency**

Plants are most likely to develop a potassium deficiency if they are grown in soil that is cold, too acidic, too dry, compacted, waterlogged or otherwise poorly aerated (or any combination of these). Other nutrient imbalances can increase the risk of potassium deficiency.

**Symptoms of Potassium Deficiency**

The most common symptom of plant potassium deficiency is yellowing of older plant leaves along the edges and/or between the veins. Leaf tissue may also die along the edges and at the tips and in extreme cases, [necrosis](https://plantprobs.net/plant/nutrientImbalances/definitions.html) may spread between the veins. Having said that, plant yields will likely be reduced before either of these symptoms appear. Plants also wilt earlier in hot weather and succumb to diseases and pest attacks more quickly and more often. Legumes will often display symptoms of nitrogen deficiency as well.

**Treating Potassium Deficiency**

If you notice signs of potassium deficiency, first improve the availability of potassium by ensuring your soil is well drained and aerated and that the pH is appropriate. Potassium is most available to plants when the soil has a pH of 6.5-7.5 but provided it's between 6 and 8, most plants should be able to obtain sufficient amounts of potassium. If it's early in the season, a cloche may help to warm the soil and improve potassium uptake. Also ensure that plants are receiving adequate water. The soil should be well drained but that doesn't mean it should be allowed to dry right out on a regular basis. They key is water as frequently as is required to keep the soil moist but not water logged. If you are adding fertiliser that is high in other [cations](https://plantprobs.net/plant/nutrientImbalances/definitions.html), change to a different fertiliser and ensure you add plenty of organic matter to the soil.

If your plants are still exhibiting symptoms of potassium deficiency after these actions and a soil test reveals the soil contains insufficient potassium, then a potassium containing fertiliser may be applied. Organic sources of potassium include kelp, wood ash and many plant residues (banana peel is particularly high in potassium). Rock powder contains a variety of nutrients including potassium. Sulfate of potash and potassium nitrate are examples of inorganic fertilisers that contain potassium. Your choice of inorganic fertiliser in particular will be influenced by the levels of other nutrients in the soil (for example sulfur and nitrogen).

**Potassium Toxicity**

Excess potassium does not appear to have a toxic effect on plants. It can induce deficiencies of other nutrients however (particularly nitrogen, calcium and magnesium) so care should be taken to avoid an excess by only ever applying potassium containing fertilisers when required and according to the directions on the packaging.

# Selenium

Selenium is an essential nutrient in animals and humans but is not generally considered to be essential to plants. It has been found to be beneficial to some plants, however anything more than a trace amount can cause symptoms of toxicity. Selenium is also toxic to animals and humans if excess amounts are ingested. Selenium is typically low on acidic soils and in high rainfall areas.

If your soil contains selenium at a concentration greater than 200 mg/kg, it would be a good idea to investigate the reason why. It would also be advisable to have some plant tissue from edible plants grown in your garden analysed and to then seek expert advice about any health effects of consuming the produce if the level of selenium is elevated.

## Selenium Deficiency

Some soils are typically deficient in selenium ‑ Australian and New Zealand soils are good examples. Plants are unlikely to show any symptoms if they aren't absorbing selenium so if you have any doubts about the amount of selenium in your plants, you'll need to have your soil or plants tested. Some laboratories cannot detect the quantities typically present in soil (they can only detect levels if they're in excess of normal amounts) so ensure that the procedures used by the laboratory you choose are sensitive enough (ask them if the test will be able to tell you whether your soil is deficient in selenium). If your soil is deficient in selenium, you can apply a selenium containing fertiliser but be sure to follow the instructions very carefully so that you don't add too much.

Even if your soil contains selenium, you may also wish to test some plants to ensure that the selenium is being taken up by your plants. If your soil contains selenium but your plants don't, ensure that the soil pH is correct and that all the other plant nutrients are correctly balanced.

Note that low selenium in plants is only really an issue if a large portion of your diet consists of food harvested from your garden (meaning that you may not consume sufficient quantities). A blood test can useful in ensuring that you are consuming sufficient selenium. If you mostly grow ornamentals, you shouldn't have to treat any detected soil deficiencies.

## Selenium Toxicity

Plants suffering from selenium toxicity may be stunted and may die earlier than usual. Leaves of affected plants may exhibit [chlorosis](https://plantprobs.net/plant/nutrientImbalances/definitions.html) or may dry and wither. Some plants can safely accumulate very large amounts of selenium while others cannot so do not be surprised if adjacent plants are affected in different ways.

A soil test can confirm toxic levels of selenium in the soil and a tissue test can confirm toxic levels of selenium in plants. Guidelines may differ in your area but generally, if the concentration of selenium in your soil is greater than 200 mg/kg it is likely that your plants are suffering from an excess amount of selenium and it would be worth ordering a plant tissue test.

If your soil contains excess selenium, investigate the cause. Your soil may for example, be being contaminated by water runoff from nearby industrial processes. Once the source of the problem is identified, you may take steps to prevent further contamination. If your soil naturally contains excess levels of selenium, ensure the pH of your soil is roughly neutral and that it contains plenty of organic matter and appropriate amounts of all the essential nutrients. If some plants still exhibit symptoms of toxicity, select species that are more selenium tolerant.

If you eat large amounts of home grown produce and a soil or tissue test revels excess levels of selenium, you may wish to have a blood sample tested for selenium to ensure you are not ingesting excess levels.

# Sodium

Sodium is not a plant nutrient but it does play a role in soil health. High levels of sodium indicate salinity problems or sodicity problems such as poor soil structure. Excess sodium can also reduce the uptake of other by plants. Note that although we are familiar with sodium in the form of table salt, there are many other salts and thus soil salt content should not be confused with sodium content.

For healthy and productive soil, you should aim for a sodium concentration of less 1.0 meq/100g (meq = milliequivalents - this is a special term used to describe the amount of some elements in soil).

High sodium levels can be remediated by watering more frequently and applying gypsum. It is also worth investigating the source of soil sodium. The use of bore water and changes in the level of the water table can affect soil sodium levels. Installing a rainwater tank can be a useful step in preventing contamination of soils with sodium. If your property is on the coast, you will probably need to grow plants that tolerate moderate to high levels of salt.

**Sulfur**

Sulfur is a [secondary macronutrient](https://plantprobs.net/plant/nutrientImbalances/definitions.html) for plants. It is a component of some plant amino acids so it is required for good protein content in plants. It also helps plants to incorporate nitrogen into proteins. Sulfur is required for the production of chlorophyll and a number of enzymes. It also helps legumes form associations with nitrogen fixing bacteria. Interestingly, the flavour and odour of mustard, onion and garlic is a result of sulfur containing compounds.

The availability of sulfur to plants is influenced by a number of factors including:

* Soil type - sulfur is easily washed out of (leached from) sandy soils and such soils are thus generally low in sulfur unless they contain large amounts of organic matter
* Organic matter - organic matter stores sulfur
* Soil temperature - cold soil prevents microorganisms from converting unavailable sulfur into available sulfur that plants are able to use
* Drainage - the microorganisms mentioned above require oxygen which poorly drained soils lack thus poor drainage reduces the availability of sulfur
* Pollution - high levels of pollution in an area can increase the amount of sulfur in the soil though this sulfur may not be in a form available to plants
* Water - water may contain high levels of sulfur but it can also leach sulfur from the soil (particularly sandy soils)
* Ammonium - adding ammonium to soil can improve the uptake of sulfur by plants

Ideally, for healthy and productive soil the you should aim for a sulfur concentration of 10‑20 mg/kg.

**Sulfur Deficiency**

Sulfur deficiency is more common in plants grown on cold and sandy soils as well as those that are low in organic matter. Sulfur deficiency is also more likely to occur in areas with high rainfall or pollution.

**Symptoms of Sulfur Deficiency**

[Chlorosis](https://plantprobs.net/plant/nutrientImbalances/definitions.html) is the main symptom of sulfur deficiency. New leaves are affected first but as the deficiency worsens, older leaves may become affected as well. [Chlorosis](https://plantprobs.net/plant/nutrientImbalances/definitions.html) is uniform across the leaf rather than being blotchy or restricted to [interveinal](https://plantprobs.net/plant/nutrientImbalances/definitions.html) areas. In some cases, affected leaves may be smaller than healthy leaves and the whole plant will usually be stunted. Maturity of the plant may also be delayed.

**Treating Sulfur Deficiency**

When plants exhibit symptoms of sulfur deficiency, your first steps should be to check (and adjust if necessary) the soil pH and increase the amount of organic matter in the soil. Sulfur is most available to plants when the pH of the soil is 6 or more though most plants should be able to uptake sufficient sulfur if the soil pH is 5.5 or higher. Additional sulfur may be required when the soil pH needs to be less than 5.5 (for example, azaleas and blueberries require more acidic soil).

Soil should have good drainage. If it doesn't, organic matter will help though it takes some time for additional organic matter to take effect. If drainage is quite poor, you may want to transplant your plant to a different position or build a raised bed for it. It's also a good idea to ensure that plants are watered only when required (don't let an automated system provide water if it's just rained for instance).

If symptoms appear early in the season, cloches can be used to warm the soil.

If soil nitrogen levels are moderate to low (according to a soil test), an ammonium containing fertiliser can be applied to the soil to aid the uptake of sulfur.

If symptoms persist, it would be a good idea to have your soil tested. If soil tests reveal a moderate or more severe sulfur deficiency, sulfur can be added to the soil directly but this acidifies the soil, which is undesirable except when growing berries or if the soil is alkaline. The preferred alternative is to use gypsum to provide additional sulfur. Other sulfur containing fertilisers are available but they can upset the balance of other elements if sulfur is the only deficient nutrient. If soil tests reveal soil deficiencies in nitrogen, potassium of phosphorus, then you could apply ammonium sulfate, potassium sulfate or super phosphate respectively. If you chose to do so, remember to always follow the directions on the packaging carefully and keep the dose small. It's much better to have to provide multiple small amounts of a fertiliser than to add a large amount and find that you've added too much of something.

**Sulfur Toxicity**

For practical purposes, sulfur toxicity should be considered impossible. Excess soil suffer can prevent the uptake of other elements though - nitrogen for example. If your soil contains excessively large amounts of sulfur, increase irrigation and ensure that fertilisers being applied to the soil do not contain sulfur. The deficient nutrient can also be added to the soil provided it doesn't result in excess levels of that nutrient in the soil, which could result in toxicity once soil sulfur levels drop.

If excess sulfur is from air pollution it can be difficult to control. If your plants are all in pots, you can replace the potting mix when required and wash the leaves regularly. If your plants are in the ground, short of replacing the soil you may just have to monitor plants for induced deficiencies and treat those as necessary.