Banksias, such as *Banksia ericifolia*, are classic phosphorus-sensitive plants from Australia

Jason Ingram / RHS

Phosphorus toxicity and Australian plants

Knowing about phosphorus is a requirement for growing some Australian plants, as ROBBIE BLACKHALL-MILES and BEN RAM explain.

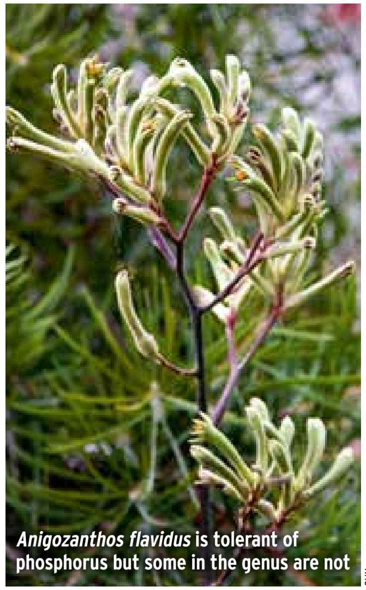
THE AUSTRALIAN FLORA has many iconic plants that are desirable for UK gardens, such as *Acacia*, *Anigozanthos*, *Banksia*, *Callistemon*, *Eucalyptus*, *Grevillea*, *Kennedia*, *Melaleuca* and *Swainsonia*. However, some of these have earned themselves a reputation for being difficult to cultivate well. Gardeners see them in flower, either in a nursery, garden or photograph and decide to give them a go. Some romp away with abandon, while others look miserable, or simply die for no apparent reason.

This article attempts to resolve a major factor that affects their successful cultivation: phosphorus toxicity. The subject was briefly touched on in these pages by Schilling (1984) but our understanding has improved since then, as has the range and availability of Australian plants.

Phosphorus geology

One of the three major macronutrients used in horticulture, phosphorus is fed to plants to encourage root and stem growth. It allows plants to take up other important nutrients and regulates protein synthesis, thereby driving cell growth.

Most phosphorus is mined in Morocco, and on a global scale it is a rare element. It becomes available on the surface of the earth when volcanoes spew it out as dust, ash and molten rock. Erosion by natural processes such as glaciation frees minerals from the rocks, which are usually then distributed while suspended in water. Some of this phosphorus becomes ocean sediment and eventually enters the cycle again as rock. Some, however, is taken up by plants and becomes locked up in their stems, bark and foliage. These eventually decompose



Anigozanthos flavidus is tolerant of phosphorus but some in the genus are not

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to form the world's organic soils.

Australia is different. The rocks are some of the oldest on the planet. Any volcanoes that did exist are long extinct and glaciers have had little impact. Wind and water have eroded the mountains into islands that poke out of an otherwise flat and sandy landscape. Geologically, Australia has been asleep for a very long time.

In the east the Great Dividing Range acts as a barrier to moisture coming in from the sea, creating a humid and high-rainfall environment dominated by lush forests that stretch from the tropical north to the cooler, temperate south. These areas have managed to hang on to what phosphorus there is available through their organic soils.

The land to the west, however, is dry. What little rain has fallen has leached much of the phosphorus away. The sclerophyll vegetation here has evolved to acquire phosphorus and be economic with it. The nutrients required to build leaves are hard fought for, so plants hold on to and protect their leaves at all costs. When leaves do get old, their nutrients are returned to the plant before falling. With little rain any leaf litter that accumulates decomposes extremely slowly. Nutrients are used as quickly as they become available and only return to the soil in any quantity by means of fire. Regeneration after fires happens quickly and uses up the available phosphorus rapidly. It is the ability of plants to take up phosphorus in these environments that affects our ability to grow them, so an understanding of their ecology is useful.

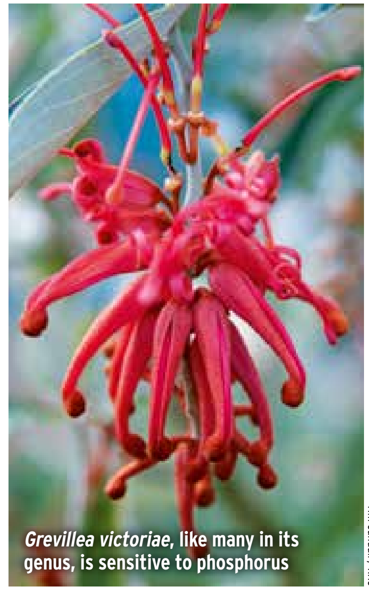
Phosphorus strategies

Plants that grow in areas with very low phosphorus have developed several strategies for obtaining it. Some chemically mine it, by exuding acidic carboxylates at their root tips, breaking down rock to make phosphorus available in the soil. The thickened cluster roots of some *Proteaceae* and *Restionaceae* are thought to be an adaptation to this lifestyle. *Fabaceae*, however, can exude carboxylates from their normal root tips. The specialist root systems that the miners use have evolved separately in several plant families.

Others have evolved different

Kennedia nigricans – species in this genus have two methods of phosphorus uptake

Liz Blyth / RHS



Grevillea victoriae, like many in its genus, is sensitive to phosphorus

Tim Sandall / RHS

strategies. Some *Ericaceae* use mycorrhizal fungi to scavenge phosphorus from a wide area, including from other plants, in exchange for carbon. Others have taken to a carnivorous diet, trapping insects and digesting them to obtain phosphorus. This has led to Western Australia having the highest diversity of *Drosera* species in the world.

In cultivation

Without close attention to these strategies for phosphorus acquisition gardeners can struggle to grow plants from these unique Australian environments. The scavengers and carnivores can generally cope with low to medium amounts of phosphorus in their growing medium without showing signs of stress. The miners, however, have little or no ability to regulate phosphorus uptake and thus suffer when more than minuscule amounts are readily available. When too much phosphorus is freely available they can overdose. This often manifests itself in leaves and stems that turn black and die, subsequently killing the plant.

It is worth noting that the strategy a plant uses to acquire phosphorus is not always simply a choice between one or the other. Some genera use a trade-off between mining and scavenging, depending on ease of availability. *Kennedia*, for example, can either use mycorrhizal fungi or carboxylate exudation, but not both at the same time. When phosphorus is available in the soil carboxylate release is suppressed, allowing mycorrhizae to colonize their roots.

Uptake of phosphorus

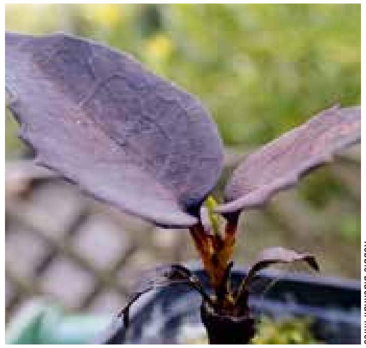
Phosphorus is a highly reactive element. It is this that makes it so useful to plants, by fuelling the chemical reactions for energy transfer. In air, phosphorus combines with oxygen to form phosphate. But for plants to uptake phosphorus it needs to be in solution with water. In soil, phosphorus is usually in an organic solid state and is not readily available without being decomposed and released into water in an inorganic state.

In areas with wet winters and dry summers plants take up phosphorus in winter and store it in their tissues, such as in their bark, until the weather gets warmer and growth restarts. It may not be until a plant starts to grow that you notice its tissue going black and dying. In cultivation, phosphorus-sensitive plants potted into a highly organic compost can suffer in the growing season. This is because too much phosphorus becomes available as the compost breaks down.

Which plants are sensitive?

If you have an Australian plant and are unsure about its sensitivity, start by finding out where it comes from in the wild and what family it is in. A good rule-of-thumb is that *Myrtaceae* can handle phosphorus whereas *Proteaceae*, *Restionaceae* and *Cyperaceae*

Tony Schilling


Robbie Blackhall-Miles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Experiment showing *Grevillea aquifolium* in media with normal (top left) and reduced (top right) levels of phosphorus. Phosphorus toxicity in a *Lomatia* seedling (above left) and *Telopea* leaves (above right).

cannot. However, some *Proteaceae* can handle higher levels and some *Myrtaceae* cannot. Western Australian species are generally more sensitive, yet rainforest species east of the Great Dividing Range are less so. *Fabaceae* and *Ericaceae* can be either way, but be aware that sudden changes in levels of available phosphorus can affect these families.

Some Australian plants come from areas with relatively normal phosphorus levels. These are easier to grow in gardens if you know which ones they are. *Grevillea robusta*, for example, handles phosphorus well since it is native to northeast Australian rainforest where phosphorus is available in the leaf litter. This allows it to be grown easily in the rich soils of UK gardens and makes it a useful candidate as a rootstock for the more phosphorus-intolerant members of its genus.

Symptoms and remedies

Plant tissue that looks blackened, yellowing or burnt may be showing signs of phosphorus toxicity. Deterioration can be quick, but there are simple methods that can alleviate decline, although they are not guaranteed due to the speed at which toxicity can occur. Iron, aluminium and calcium react with and lock up phosphorus in soil at different pH levels.

Phosphorus is most available at a slightly acid to neutral pH (5.5–7). Most plants that are phosphorus-sensitive come from acidic soils, so at pH5.5–7 addition of sulphur in the form of a metal sulphate solution is the best method of acidifying the soil. Once your soil is at pH4–5 the addition of aluminium sulphate will best lock up available phosphorus. Below this pH, iron, as iron sulphate, better fixes phosphorus.


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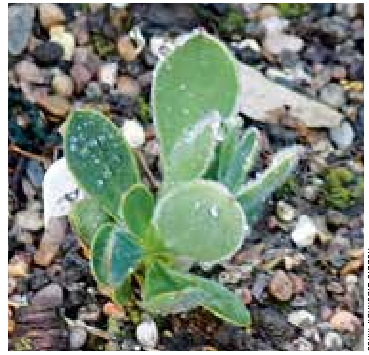
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Cluster roots of a *Banksia* showing the typical close spacing of lateral rootlets (left) and a *Protea* seedling with a healthy level of phosphorus (above left), and still looking healthy at one year old (above right).

Iron, however, will bond with phosphorus to some extent at all acidic pH levels. Therefore, watering in iron sulphate as soon as symptoms occur is the best course of action. Prevention is better than cure and a regular dose of iron sulphate is recommended for all sensitive plants that grow in acid soils.

If your plant comes from an alkaline soil in the wild, a high pH can be achieved by adding calcium carbonate, which will also lock up phosphorus.

For all additions of metal sulphate and calcium carbonate, follow the dosage instructions on the packet.

Seeds

Seeds produced by plants in low-phosphorus soils do contain high levels of the element in their endosperm. This gives them the ability to grow quickly after germination. Once this supply is used up the seedlings need to access phosphorus from the soil, such as from ash after a fire. These plants have often evolved germination cues associated with fire, such as heat, or chemicals in smoke, or both. They are therefore used to having a comparatively high amount of phosphorus available at this stage of their growth. In cultivation this means it can be beneficial to provide phosphorus in the form of a weak solution of balanced liquid feed to seedlings just after the true leaves emerge. However, seedlings will often grow sufficiently well with a zero-phosphorus feed.

Growing media

The speed with which an organic compost breaks down dictates the rate at which phosphorus will become available. It is important that a growing medium contains some organic matter but this should have a high lignin content, such as bark, pine needles, coir or peat, that breaks down slowly.

The rest of the growing medium should consist of inorganic material such as sand, gravel, pumice or perlite. The choice and ratio of inorganic components in the growing media should reflect the water requirements of the plant.

Phosphorus-sensitive plants potted into growing medium with a low organic content still need other nutrients. These can be provided in the form of a low-phosphorus fertilizer. Examples of these include seaweed extract, sulphate of potash, sulphate of ammonia, dried blood (but not bone, which contains phosphorus) or a liquid or slow-release fertilizer with low phosphorus (usually sold as a feed for *Proteaceae*). Feed should be given as per label when plants are in active growth.

Conclusion

The plants of Australia seem very different from those we are used to in the northern hemisphere. They are certainly rewarding to grow for all levels of expertise. While some are relatively easy to cultivate, others do require some thought, but an understanding of their phosphorus requirements will mean that more of us can enjoy growing them well.

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REFERENCE

Schilling, T (1984) *Proteaceae* – a survey of the hardier species. *The Plantsman* 6(3): 129–151