Managing cadmium in summer grain legumes for premium quality produce

Consumer demand for premium quality products is increasing. Concern about the presence of chemical impurities has resulted in monitoring and research into food quality in Australia. Cadmium has been identified as being of potential concern.

Compiled by Agency for Food and Fibre Sciences, QDPI Kingaroy; Natural Resource Sciences, NR&M Indooroopilly; and CSIRO Land and Water, Adelaide.

What is cadmium?

Cadmium is a widespread naturally occurring element, that is present in soils, rocks, waters, plants and animals. It occurs naturally with deposits of zinc, but unlike zinc is not essential to life. Cadmium can accumulate in humans, and high levels can affect human health.

Australia has a National Cadmium Minimisation Strategy which aims to protect and improve the quality of agricultural produce.

Why is cadmium a problem?

- There is a smaller safety margin in foods, between levels of cadmium and regulatory health limits, compared to other heavy metals such as lead and mercury.
- Cadmium is concentrated in particular parts of plants. As a general rule, leaves contain the most, followed by storage roots and tubers, seeds or grain and fleshy fruits. However, grain legume seeds can contain as much cadmium as leaves and stems.
- Human intake of cadmium occurs through food consumption, smoking and occupational exposure.
- Cadmium accumulates in the body, principally in the kidneys, leading to gradual kidney damage if exposure is high over a long period. While it is anticipated that the Australian population is unlikely to experience cadmium related health problems, the potential for any increased health risk should be addressed.

In Australia, greater use of phosphate rock with lower cadmium content used for manufacturing, and finished fertiliser with low cadmium content, has reduced cadmium inputs to soils.

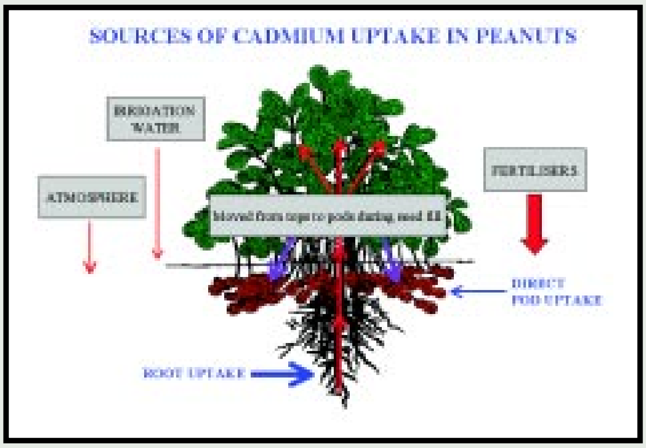
Sources of cadmium

- Natural levels in Australian soils range from less than 0.1 mg/kg to 0.5 mg/kg, or about 0.1 to 0.7 kg cadmium/hectare in the top 10 centimetres of soil. The distribution down the profile is affected by cultivation practices.
- Rain and irrigation water generally have very low cadmium concentrations. Biosolids (sewage sludges) contain some cadmium as an impurity.
- Cadmium in the atmosphere may be high in the vicinity of industrial activities such as smelting, but in most agricultural regions the amounts added to the soil from the atmosphere are minimal.
- Phosphatic fertilisers can contain high levels of cadmium depending upon the source of phosphate rock used in manufacturing. The Fertiliser Industry Federation of Australia Inc. (FIFA) initiated a program in the early 1990's to progressively reduce the levels of cadmium in phosphatic fertilisers by incorporating lower cadmium content phosphate rock in the manufacture of superphosphate and importing low cadmium content high P analysis fertilisers.
- Currently the maximum permitted concentration of cadmium in phosphatic fertilisers is 300 mg cadmium per kg of phosphorus. The concentrated phosphatic fertilisers presently used in Australia, i.e. DAP, MAP and TSP, are low in cadmium (mostly less than 100 mg cadmium per kg P). The pasture grades of single superphosphate are higher in cadmium, typically containing less than 250 mg cadmium per kg P. Premium grades of single superphosphate developed for horticultural use contain less than 100 mg cadmium per kg P and are available in some States.
- Trace element fertilisers and phosphogypsum also may contain high levels of cadmium. In Queensland, the maximum permitted concentration of cadmium in these materials is 50 and 15mg cadmium per kg of product, respectively.
- Nitrogen and potassium fertilisers normally have very low cadmium content.
- Mill (or filter) muds produced in sugar mills also contain some cadmium - typically 0.3 mg/kg.

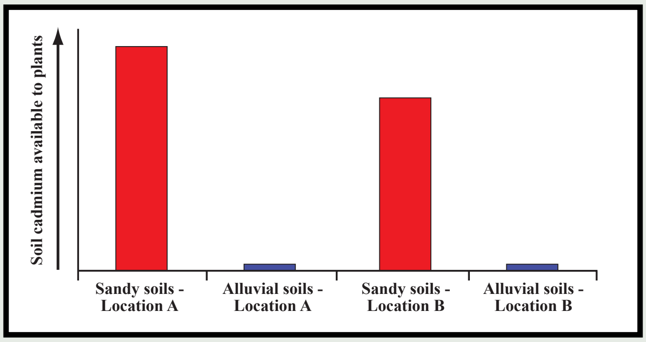
Cadmium levels in Australian food and exports

- Dietary intake of cadmium in Australia is low by world standards and our food exports have a “clean” reputation worldwide. To maintain this quality advantage we need to minimise any potential cadmium accumulation in food products.
- The Australia New Zealand Food Authority sets the maximum levels of cadmium in various food products, considering public health, food safety and consistency between domestic and international food standards.

How do plants take up cadmium?

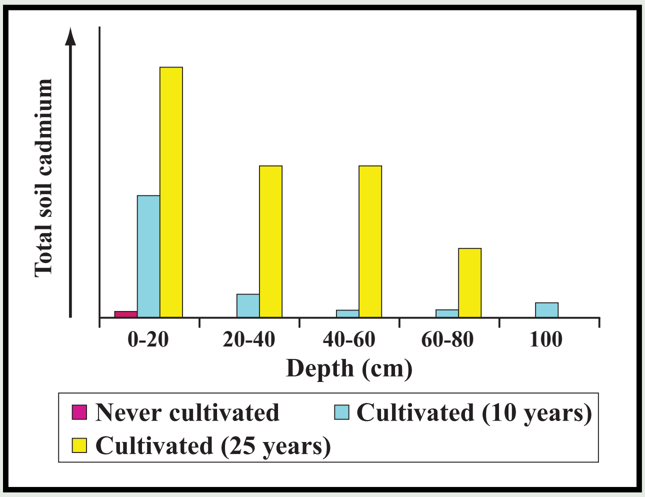


- Plants absorb most of their cadmium from soil through their roots, although peanuts can also absorb small but significant amounts of cadmium directly through the pod walls.
- Cadmium in soil readily attaches to clay particles and organic matter, making it less available for uptake by plants. Sandy soils with low clay content and organic matter are likely to result in more plant available cadmium and a higher uptake.
- The availability of cadmium to plants decreases as soils become more alkaline (soil pH increases).
- Zinc and cadmium uptake by plants occurs in a similar way, and research suggests that if soil zinc levels are low then more cadmium will be taken up.
- Cadmium in soil tends to remain in the cultivated layers where it is available to plants. It can be removed by erosion or by leaching from very light sandy acid soils.



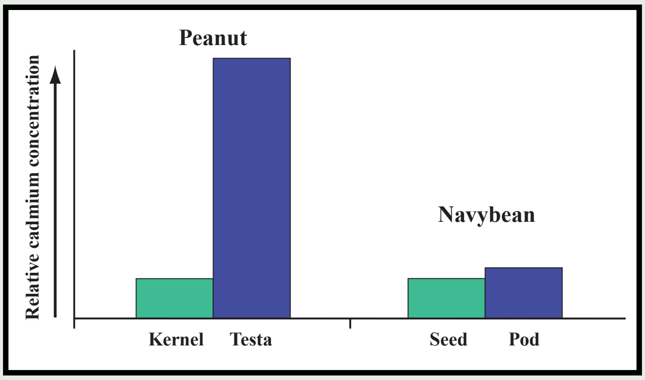
Soil characteristics play a major role in the availability of soil cadmium for plant uptake.

- Uptake varies considerably between different plant species and between varieties or cultivars.
- Peanuts preferentially move zinc, rather than cadmium, from leaves and stems into the developing kernel during pod filling. This discrimination has not been observed in other species.



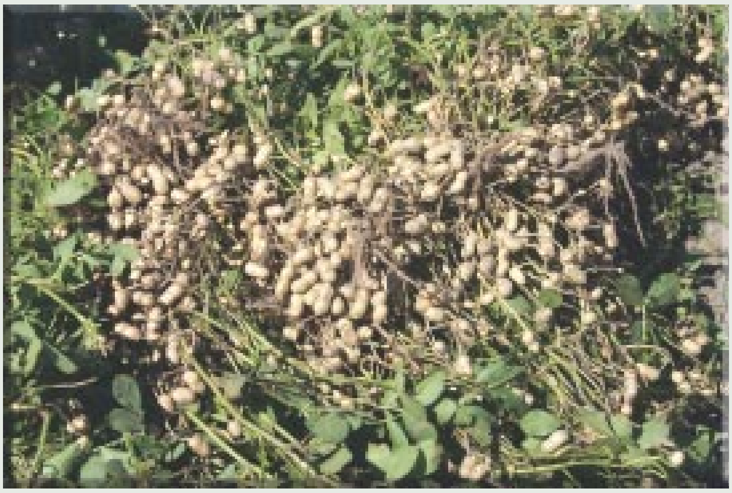
Most cadmium in soil profiles accumulates in the cultivated layer, with depth varying with tillage practices. Cadmium tends to accumulate with increasing time under cropping.

- The skin (testa) around the peanut kernel can be a highly effective filter that reduces cadmium loading into the developing kernel. However, in situations of high plant cadmium uptake the testa becomes saturated and much less effective. The pod wall of other grain legumes has been shown to be a much poorer cadmium filter.



Cadmium distribution between plant parts varies with species.

- Cadmium present in farm produce can also be the result of soil or dust contamination either in the field or during processing, as well as by direct uptake from the soil.
- Higher concentrations of chloride in the soil mobilise cadmium and increase uptake by plants. This can occur from irrigation with saline water, in areas subject to dryland salinisation, or from the intensive use of chloride based fertilisers.



There are no visual symptoms to indicate if a plant has high cadmium.

How do you know you have a cadmium problem?

Visual symptoms can be evident when plants are grown in grossly contaminated soils in industrial or urban areas. However, you can not tell visually if a plant has high cadmium when grown in normal agricultural soils – the concentration needs to be measured. There are no critical levels of cadmium in agricultural soils to protect food quality.

Soil and plant tissue tests for cadmium are not routinely performed by most laboratories. Nevertheless, conventional soil tests are of value in soil and crop management. Soil tests for pH, organic carbon, salinity, phosphorus and zinc provide valuable information in managing cadmium accumulation. Irrigation water should be checked for its salinity as chloride stimulates plant uptake of cadmium. Plant tissue tests for cadmium are best performed on the marketable produce.

The Australia New Zealand Food Authority currently has set a limit for peanuts in the domestic market of 0.10 mg/kg cadmium on a fresh weight basis. There are currently no such limits for grain legumes like soybeans and navybeans, although exporters may have to meet limits set by the importing country (eg. less than 0.2 mg cadmium/kg for the European Union).

A regular testing program of the harvested crop is recommended.

Contacts for further information

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Management practices to minimise cadmium levels

Choice of crop species

Data collected from QDPI/NR&M and CSIRO trials have suggested there are large differences between summer grain legume species in susceptibility to cadmium uptake. This ranking is generally:

Peanut >> Soybean > Navybean.

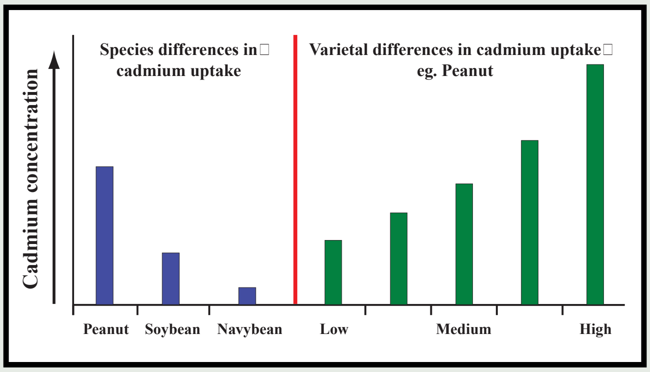
Varietal selection

Variety trials with both peanut and soybean have also shown significant cultivar variation in cadmium accumulation. Data collected from a number of variety trials have suggested the following variety ratings for susceptibility to cadmium uptake in peanut:

High cadmium accumulators
NC7, Conder, VB97 and most Spanish varieties

Medium – Low cadmium accumulators
Florunner, Southern Runner, Streeton

Soybean data are less conclusive, with unexplained variation in relative cadmium uptake between varieties at different sites. Soy 791 has been one of the few consistently low cadmium accumulators.



Select crop species and varieties with low or medium susceptibility to cadmium uptake.

Correction of soil acidity.

Peanuts, and to a lesser extent soybeans, are tolerant of acidic soils and hence yield increases by liming are unlikely. However, the calcium from lime aids pod filling in peanuts grown on sandy soils.

Field studies have shown that lime applications alone have had little or no effect on kernel cadmium concentrations in peanut – either in the year of application or in up to two subsequent crops. However, lime applied in combination with organic matter additions (ie. incorporation of sugar cane trash) and zinc fertiliser greatly reduced plant-available cadmium in the soil and kernel Cd.

Surveys of a large number of commercial peanut and soybean fields have also shown raising soil pH and increasing organic matter content were strongly correlated with reduced plant-available cadmium and plant cadmium uptake.

A liming program is needed in highly acid soils.

In highly acid soils (pH in water of less than 5.5) a liming program should be initiated to increase soil pH. Aim to maintain soil pH (water) between 6.0 and 6.5, but be sure to avoid over-liming, that can induce problems of micronutrient deficiency.

Liming immediately prior to peanut crop planting is ineffective and may even result in increased kernel cadmium concentrations. Lime must be applied 2-3 years prior to peanut crop planting as part of soil management in the rotation.

Use of fertilisers and soil amendments with low cadmium content

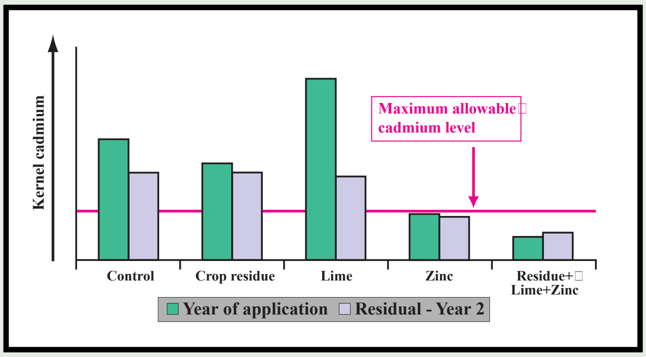
It is recommended that low cadmium fertilisers and soil amendments be used. The impact of this on reducing seed or kernel cadmium levels at sites with a long phosphate fertiliser history is only likely to occur over the medium to long term. Your supplier will be able to advise you on the cadmium content of these products.

In the case of phosphatic fertilisers, look for materials with less than 150 mg cadmium per kg of phosphorus. Such products are commercially available. Where repeated high applications of phosphorus (that is greater than 50 kg per crop) are anticipated, fertilisers of less than 100 mg cadmium per kg of phosphorus are desirable. Where a paddock has adequate soil phosphorus levels for summer grain legumes (for critical levels consult your local agronomist) phosphorus need not be applied.

Management practices to minimise cadmium levels

Other sources of cadmium in fertilisers or soil amendments commonly used in summer grain legumes include fertiliser zinc (applied to soil or as a foliar spray) and gypsum. Organic wastes such as manures from intensive livestock and poultry industries may also contain significant amounts of cadmium, depending on the source. Check with suppliers to choose a product with an acceptably low cadmium concentration.

Gypsum can play an important role as a soil amendment to reduce hard setting surface crusts or waterlogging. It is also being commonly used as a soluble source of calcium to aid pod filling in peanuts on sandy soils. Naturally occurring (mined) gypsum should be used in place of phosphogypsum - particularly in peanut crops or if cadmium uptake is already high. Phosphogypsum is a by-product from the manufacture of phosphatic fertilisers, and can contain significant amounts of cadmium, depending on the source (check with your supplier for product quality).

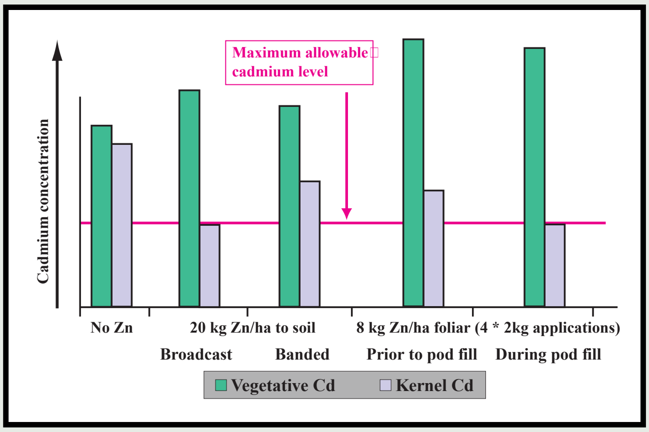


An example of kernel cadmium levels in response to soil amendments including lime on an acid sandy soil.

Addition of zinc

Application of fertiliser zinc has been found to significantly reduce cadmium concentrations in peanut kernels. This effect was even more pronounced when zinc fertilisers were applied to soil in combination with additions of lime and organic matter. The responses to added zinc are much smaller and practically ineffective in other grain legume species.

The reduction in peanut cadmium is a direct result of preferential movement of zinc, rather than cadmium, into developing kernels. As a result, foliar applications of zinc during pod filling have been found to be just as effective as much larger soil zinc applications in reducing kernel cadmium.



Effect of zinc application methods on peanut kernel cadmium concentration.

Applications of foliar zinc, or zinc broadcast and incorporated into the soil are suggested as a trial where the concentration of extractable zinc (DTPA) in the soil is less than 1 mg/kg (1 ppm). Rates needed to reduce cadmium concentrations are generally higher than that needed to overcome zinc deficiencies, and 30-100 kg zinc as zinc sulphate heptahydrate/ha could be used for soil applications (consult your agronomist). For foliar applications, rates of 1-2 kg zinc as zinc sulphate heptahydrate/ha are suggested on 3 or 4 occasions during pod filling (again consult your local agronomist).

Zinc deficiency is commonly observed in the sandy soils favoured for irrigated peanut and navybean production, and in coastal areas growing soybeans in rotation with sugarcane. It is therefore likely that zinc fertiliser will increase crop yields as well as minimise seed cadmium concentrations. Any effect of zinc on seed/kernel cadmium should last several years if zinc is soil applied. Foliar applications will need to be applied to each crop. Note that excessive applications of zinc will result in plant toxicity, especially in peanut crops grown on acidic sandy soils.

Cadmium content of the zinc fertiliser should be checked before using (less than 50 mg cadmium per kg product), as the cadmium content of trace element products can be higher than standard NPK fertilisers.

Selection of nitrogen and potassium fertilisers to minimise cadmium uptake

There has been little work done on the impact of other common fertilisers on cadmium content of the summer grain legumes. In other crops, changing nitrogen fertiliser has had little impact on plant cadmium concentrations. However, changing from potassium chloride to potassium sulphate has decreased cadmium concentrations in potatoes by up to 30% in areas where chloride in soil and irrigation water is low. Unfortunately, potassium sulphate costs more.

Management practices to minimise cadmium levels

Avoid use of irrigation water with high chloride levels

Field experiments with other crops have shown that increased chloride content in the topsoil will increase cadmium availability. A major source of chloride is likely to be saline irrigation water. Irrigation waters with greater than 450 mg/litre chloride, or total dissolved salts greater than 750 mg/litre (equivalent to an electrical conductivity of about 1.2 dS/m), have a high risk of increasing cadmium concentrations in summer grain legumes.

High soil chloride may also occur in areas subject to increasing dryland salinisation, due to rising groundwater levels. No research has been carried out to confirm this, but as a precautionary measure it is recommended that summer grain legumes not be grown in these areas.

Maintain or increase soil organic matter

There is good evidence that organic matter helps to reduce cadmium availability to summer grain legumes.

Soil organic matter is generally built up by:

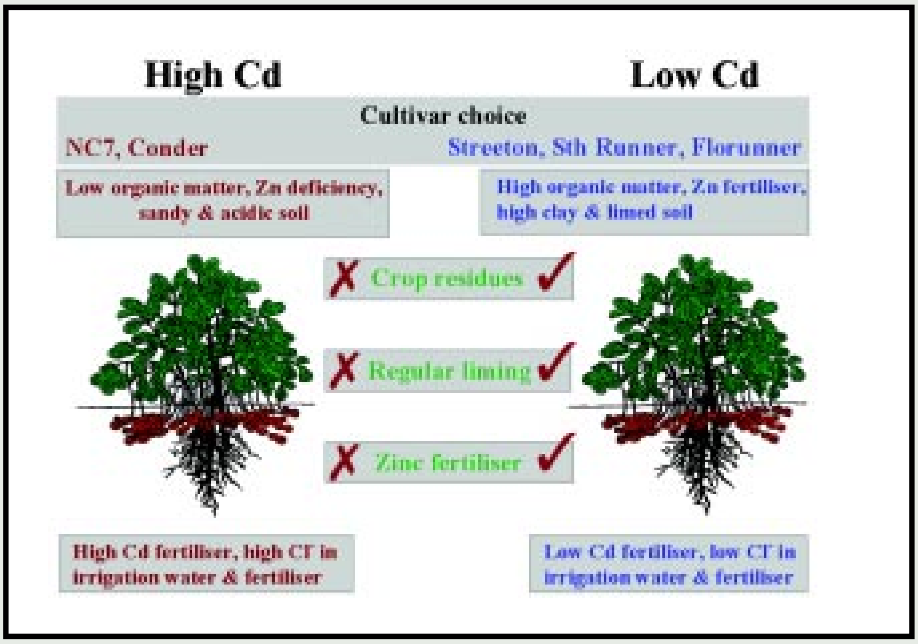
- the retention of crop residues after harvest
- use of green manure crops
- pasture phases in crop rotations
- significantly reducing the number of crop cultivations

The build-up or breakdown of soil organic matter is a slow process and significant changes only occur in the medium to long term, unless organic matter is introduced from external sources such as manures.

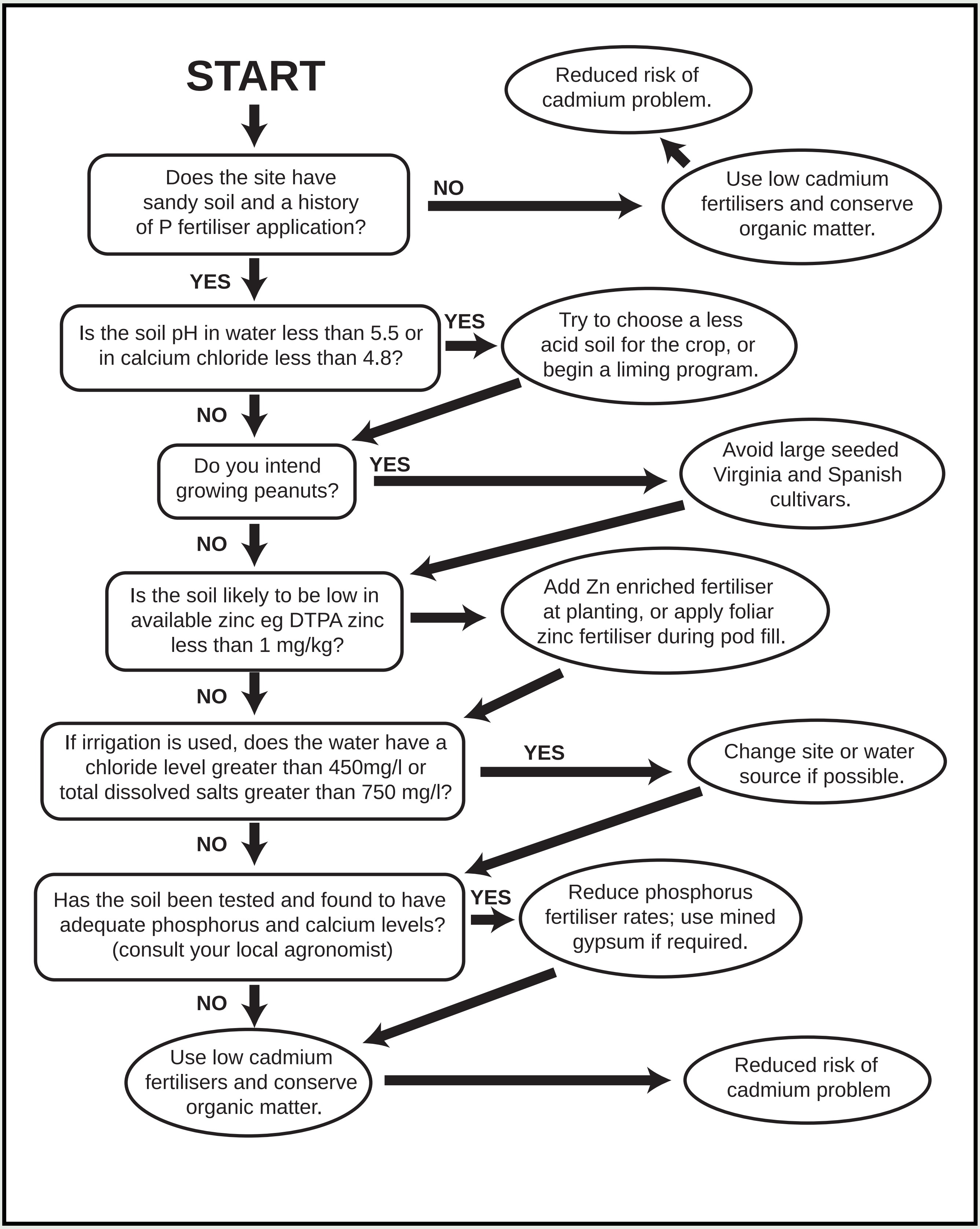
Areas subject to dryland salinisation may result in elevated plant cadmium uptake.

Retaining and incorporating sugarcane trash, rather than burning, can make a significant contribution to soil organic matter levels and reduce cadmium availability.

An integrated management approach holds the key to minimising cadmium



Management practices to minimise cadmium levels



Managing cadmium effectively means implementing a range of practices as a total system. In paddocks where seed/kernel cadmium concentrations are already high, the impact may be small in the short term. Sound management will be essential to assist control of long term cadmium levels.