# Soil Stamina ~ Understanding Soil Acidity

Acidity and alkalinity in any solution is measured as pH. The pH of soil indicates the strength of acidity or alkalinity in the soil solution which bathes soil constituents, plant roots and soil micro-organisms. Soil is neutral when pH is 7, it is acid when pH is less than 7 and alkaline when it is greater than 7. The pH scale is logarithmic, so a difference of a unit is a tenfold difference in acidity or alkalinity (eg. pH 5 is ten times more acid than pH 6).

Most soil pH measurements in Australia are made by shaking soil samples for an hour in either a 1:5 soil to water suspension (pHw) or a 1:5 soil to 0.01M calcium chloride suspension (pHCa) and using an electrode to measure the pH of the resultant mixture. (Upjohn, Fenton, & Conyers, 2005)

The pH measured in calcium chloride is on average 0.5 to 0.8 less than pH measured in water, although the difference can vary from nil to 2.0 for different soils.

Soil pH was mapped across Victoria using a statewide soil chemistry data set based on samples submitted from farms, vineyards and orchards between 1973 and 1994. Each sample was a composite of 20 to 30 cores representing the 0-10, 0-15 or 0-30 cm depth of soil taken from the main soil type in each paddock. Samples from national parks, urban land and sport and recreational turf were excluded from the data. Collated data included nearest location and pH (1:5 soil:water). (DPI)

A map was generated by applying geo-statistical techniques (‘kriging’) to the mean pH of the locations. It indicates the geographic trends in the acidity and alkalinity of surface soils across Victoria's agricultural land. This map cannot indicate soil pH at the paddock scale and it should only be used as an indicator of likely pH at a regional scale. Considerable variations in soil pH will occur within a region. This map does not substitute for a soil test and can be found at http://www.dpi.vic.gov.au/dpi/vro/map_documents.nsf/pages/surf_ph.

Basically it shows that soils in south west Victoria are acid soils. This is confirmed by the new Caring For Our Country federal funding program which has identified this area as a priority for funding for acid soils. (www.nrm.gov.au)

Acidification of the soil is a slow natural process and part of normal weathering. Many farming activities cause an increase the rate of acidification of the soil. Changes in soil pH under agricultural use are measured in tens or hundreds of years rather than thousands of years as in the natural environment.

Agricultural practices have acidified soils. For example; soils under subclover based pastures, leguminous crops such as lupins, and where ammonium fertilisers are used. Management practices can be used to reduce the impact of acidification. These include use of perennial and deep rooted species (eg. phalaris) and avoiding acidifying fertilisers. Ultimately, application of lime will be needed to combat acidification. (Department of Primary Industries)

Soil pH affects the availability of soil constituents to plants and soil micro-organisms. For most plants, the ideal soil pH (water) test result is pH 6 - 7.5, although many will tolerate pH 5.5 - 8.5. However, the tolerance to extremes in pH varies between plant species and within species. Some plant species have quite different preferred pH ranges (eg. lucerne 6.0 - 8.5, celery 6.0 - 7.0, potatoes 5.0 - 6.0). Therefore, consideration of the need for soil amelioration will depend on individual circumstances.

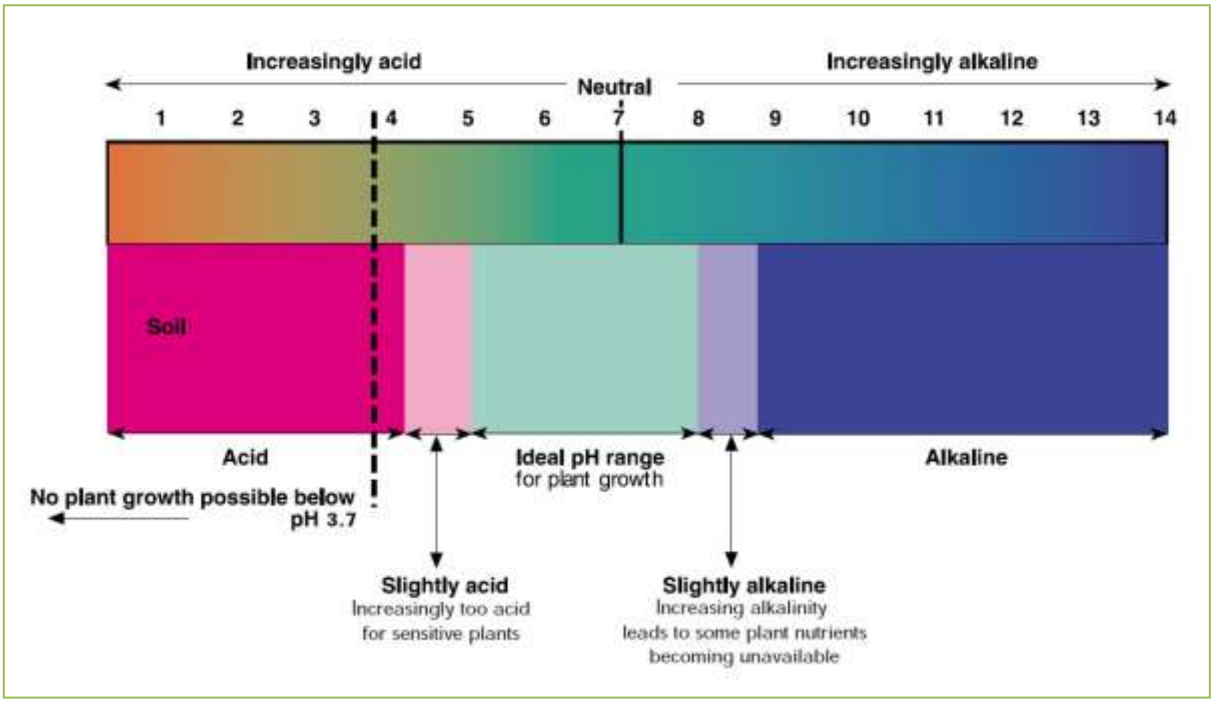


*Fig. 2. Plant growth and pH scale*
*Source: Understanding Soil pH, Acid Soil Management, NSW Acid soils action program*

A soil pH(CaCl2) of 5.2 to 8.0 provides optimum conditions for most agricultural plants (Figure ). All plants are affected by the extremes of pH but there is wide variation in their tolerance of acidity and alkalinity. Some plants grow well over a wide pH range, whilst others are very sensitive to small variations in acidity or alkalinity.

The pH of the surface soils in Victoria ranges from pH 4 to pH 10. In south west Victoria, the soils are more prone to acidity. These extremes in alkalinity and acidity present problems for the production of many agriculturally important plant species and their symbiotic rhizobia. Due to the complexity of soil chemistry, it has often been difficult to confidently identify the cause of poor plant growth or nodulation. However, aluminium and manganese toxicities and molybdenum and phosphorus deficiencies are probable causes of poor production in many strongly acid soils.

Microbial activity in the soil is also affected by soil pH with most activity occurring in soils of pH 5.0 to 7.0. Where the extremities of acidity or alkalinity occur, various species of earthworms and nitrifying bacteria disappear. Legume root colonising bacteria (Rhizobia) vary in their sensitivity to soil pH and have preferred ranges in which they are effective. In some crops and pastures (e.g. faba beans and lucerne) the Rhizobia specific to these plants are more sensitive than the plant itself.

Soil pH affects the availability of nutrients and how the nutrients react with each other (Figure 2). At a low pH, beneficial elements such as molybdenum (Mo), phosphorus (P), magnesium (Mg) and calcium (Ca) become less available to plants. Other elements such as aluminium (Al), iron (Fe) and manganese (Mn) may become more available and Al and Mn may reach levels that are toxic to plants. The changes in the availability of nutrients cause the majority of effects on plant growth attributed to acid soils. Sensitive crops such as barley and lucerne can be affected by small amounts of exchangeable aluminium. (Lake, 2000)

Soils with a low pH (less than pH 5) result in chemical imbalances such as aluminium toxicity and deficiencies of phosphorus and trace elements such as calcium and molybdenum. Very low pH (less than pH 4) leads to soil physical breakdown where the clay structure of the soil is broken down. Acid soils also impact on soil biota, reducing earthworm numbers and making Rhizobia less effective. (Hollier, 2006)

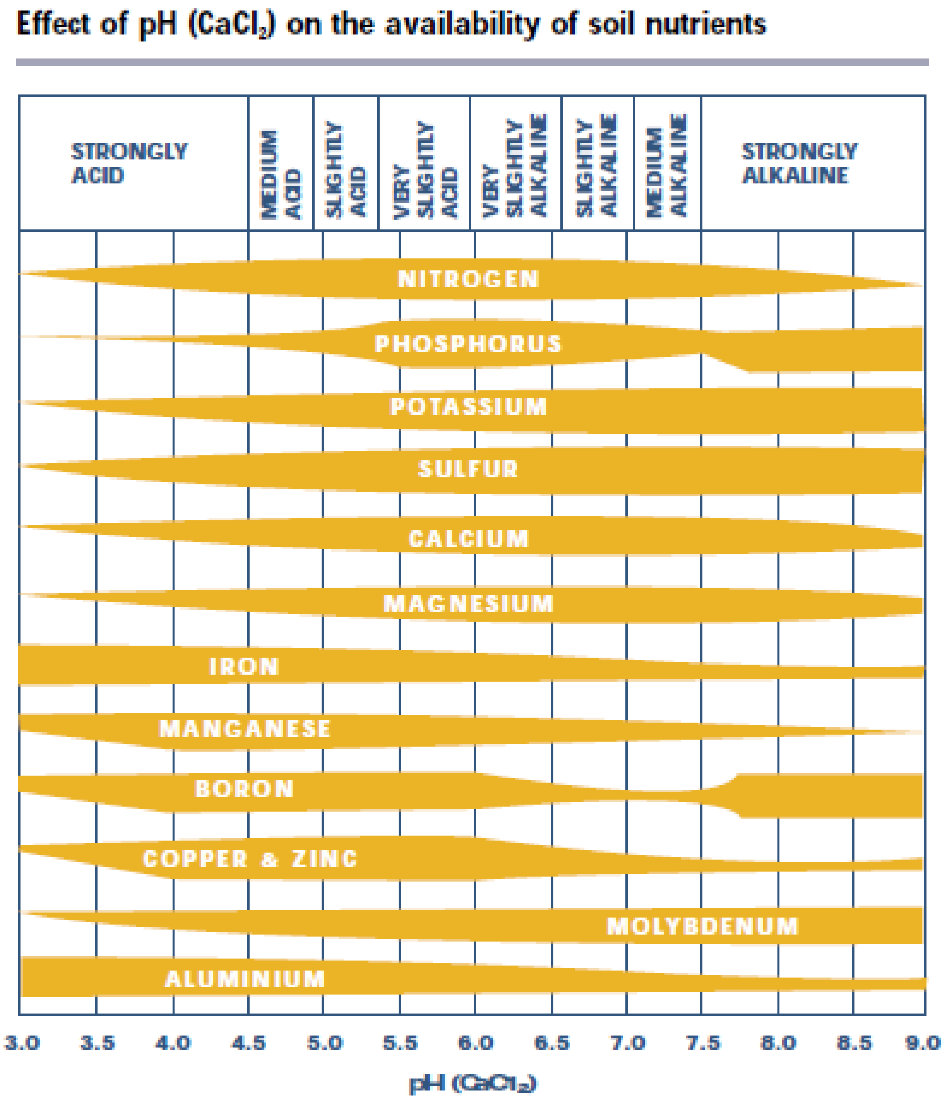


*Fig 2. Effect of Ph on the availability of nutrients*
*Source: Understanding Soil pH, Acid Soil Management, NSW Acid soils action program* (Lake, 2000)

Aluminium (Al+++) and sodium (Na++) cations are not plant nutrients, so are not wanted by the plant. Aluminium is not present as a cation when soil pH (CaCl2) is over 5 because it is precipitated out of the soil solution. It is only at pH (CaCl2) levels below 5 that it may become available as a cation, and under 4.5 may become available in toxic levels, displacing other cations from the clay or humus colloids. This is one reason why it is important to maintain pH levels at 5.0 or more. (DPI)

### Four main causes of soil acidification

According to (Schumann, 1999), and a further study by Upjohn et al, the four main causes of soil acidity are:

- removal of product from the farm or paddock
- leaching of nitrogen below the plant root zone
- nitrogenous fertilisers
- build up in organic matter (Schumann, 1999) (Upjohn, Fenton, & Conyers, 2005)

### *Removal of product.*

Obviously the main aim of any agricultural production system is to produce saleable products. However most agricultural products are slightly alkaline so their removal from a paddock or farm leaves the soil slightly more acidic. The degree of acidification will depend on how alkaline the product is and how many kilograms of product are removed. Where little actual product is removed from the farm, such as in wool production, the system remains largely in balance. The most acidifying forms of agricultural production are operations such as lucerne hay cutting. For instance the removal of one tonne of lucerne hay requires 70 kg of lime to neutralise the resulting acidity.

Cutting and removing large quantities of hay, especially lucerne, will increase soil acidity, unless balanced by lime use  If the produce is sold off-farm, regular liming is the only way to maintain pH. The effect on soil acidity of removing hay will be greatly reduced if the hay is fed back in the paddock where it was cut.

### *Leaching of nitrogen.*

Leaching of nitrogen in the nitrate form is a very important factor in soil acidity. Nitrate is a major nutrient for plant growth. It is supplied either from nitrogenous fertilisers or atmospheric nitrogen fixed by legumes. When there is more nitrate than the plant can use, the nitrate is at risk of draining - leaching - below the plants roots and into the ground water system. This leaves the soil more acidic. Leaching of nitrate can happen through inappropriate use of nitrogen fertilisers and is more common in intensive production like horticulture - or because the plants are not at a suitable stage of growth to use the available nitrogen. Pastures based on annual species, the use of long fallow in crop rotations and heavy applications of nitrogen fertilisers are examples of practices that may increase the risk of nitrate leaching.

### *Use of nitrogenous fertilisers.*

The amount of acid added to the soil by nitrogenous fertilisers varies according to the type of fertiliser. The most acidifying are ammonium sulfate and monoammonium phosphate (MAP), followed by diammonium phosphate (DAP). Less acidifying are urea, ammonium nitrate and anhydrous ammonia. Fertilisers such as sodium and calcium nitrate are not acidifying. Superphosphate has no direct affect on soil pH. However, its application stimulates growth of legumes and clovers which fix nitrogen. This increases the amount of nitrate nitrogen in the soil increasing the potential for leaching and consequent soil acidification.

### *Build-up of organic matter.*

Over the last 50 years the regular use of fertiliser and improved pastures, particularly subterranean clover, has increased the amount of organic matter in the soil. While organic matter has many beneficial effects including improving soil structure, the increasing amount of organic matter may make the soil more acid. However, organic matter will not build up indefinitely, and when an equilibrium is reached the acidification process stops.

The acidification caused by a build up in organic matter is not permanent and can be reversed if the organic matter breaks down. However, there will be a permanent change in the acid status of the soil if the topsoil containing the organic matter is eroded or removed.

It is important to differentiate between a natural build up in organic matter and the build up that occurs by adding organic material from another site. Where organic matter build up occurs due to transported material the increased organic matter generally increases pH (less acid). (Schumann, 1999) (Upjohn, Fenton, & Conyers, 2005)

### Effect of soil acidity on the micro-organisms that affect plant growth

Sometimes the effect of acidic soils on the growth and production of crops and pastures is not direct but rather through the effect on soil micro-organisms that in turn affect plant growth.

Acidity reduces the survival of Rhizobia and the effective infection of legume roots. The sensitivity to acidity varies greatly between species. When a Rhizobia sp is affected by soil acidity it shows as poor nodulation and results in reduced nitrogen fixation. Often Rhizobium bacteria are more sensitive to soil acidity than the host plant, for example lucerne and medics.

Lime pelleting of inoculated legume seed is used to protect the inoculum against drying out and contact with fertiliser. Sowing into bands of lime-super also creates an environment suitable for survival of the inoculum in an acidic soil. (Upjohn, Fenton, & Conyers, 2005)

### Managing soil acidity with limestone

According to Upjohn et al, application of finely crushed limestone, or other liming material, is the only practical way to neutralise soil acidity. Limestone is most effective if sufficient is applied to raise the pHCa to 5.5 and it is well incorporated into the soil. Where acidity occurs deeper than the plough layer, the limestone will only neutralise subsurface soil acidity if the pHCa of the surface soil is maintained above 5.5. Liming to increase the pH of the surface 10 cm significantly above 6.0 should be avoided as it may induce deficiency of other plant nutrients such as zinc, boron and manganese in well weathered soils.

The liming materials most commonly used are agricultural limestone and dolomite, but other materials are available.

The neutralising value (NV) of a liming material is its capacity to neutralise acidity. The higher the NV the more pure is the product. Pure calcium carbonate (pure limestone) is taken as the standard with an NV of 100. The neutralising value of commercial limestone is usually between 96 and 98.

The finer particles in a liming material react more quickly in the soil as they have a greater surface area to react with acids. Secondly they will be better distributed through the soil after incorporation. Most lime crushers strive to produce a lime that has a particle size where 90% passes through a 150 μm sieve. Lime where 99% is less than 75 μm is highly reactive but requires special machinery to spread. Particles larger than 500 μm react only very slowly with the soil. (Upjohn, Fenton, & Conyers, 2005)

Apply limestone before the most acid sensitive crop or pasture in a rotation as it gives the best economic return. If the limestone will not be effectively incorporated due to reduced tillage, then apply the limestone a year before the most sensitive crop and apply it at a slightly heavier rate. These two actions will enhance lime movement into the top soil. The time of the year when lime is applied is not important.

Limestone begins to become effective as soon as the soil is moist and reaches its major impact after 12 to 18 months. Applying limestone to permanent pastures is often not economic as there is no incorporation of the limestone and the pasture species are generally acid tolerant and will give only a limited response. In sandy soils and where the annual average rainfall is greater than 600 mm, limestone applied to the surface may move to 10 cm depth in 2–3 years. As the clay content in the soil increases, or the rainfall decreases, there is less movement of limestone down the profile. A rapid response to surface applied limestone is most likely caused by release of molybdenum or improvement in legume nodulation, and the release of nitrogen from organic matter.

**Table 11. Limestone required (fine and NV > 95) to lift the pH of the top 10 cm of soil to 5.2.**
**Colour codes group limestone rates to the nearest 0.5 t/ha**

| Soil test ECEC (meq/100 g) | Lime required (t/ha) to lift the pH of the top 10 cm: | | | |
|---|---|---|---|---|
| | from 4.0 to 5.2 | from 4.3 to 5.2 | from 4.7 to 5.2 | from 5.2 to 5.5 |
| 1 | 1.6 | 0.8* | 0.3* | 0.2* |
| 2 | 2.4 | 1.2 | 0.5* | 0.4* |
| 3 | 3.5 | 1.7 | 0.7 | 0.5* |
| 4 | 3.9 | 2.1 | 0.9 | 0.6 |
| 5 | 4.7 | 2.5 | 1.1 | 0.7 |
| 6 | 5.5 | 3.0 | 1.2 | 0.8 |
| 7 | 6.3 | 3.3 | 1.4 | 1.0 |
| 8 | 7.1 | 3.8 | 1.6 | 1.1 |
| 9 | 7.9 | 4.2 | 1.8 | 1.2 |
| 10 | 8.7 | 4.6 | 1.9 | 1.3 |
| 15 | 12.5 | 6.7 | 2.8 | 1.9 |

*It is recognised that low rates of lime are impractical to apply, but over-liming can cause nutrient imbalances, particularly in these light soils.

**KEY: Limestone rates per hectare**

| 0.5 t/ha | 1.0 t/ha | 1.5 t/ha | 2.0 t/ha | 2.5 t/ha | 3 to 4 t/ha | Split applications advised |
|---|---|---|---|---|---|---|
| | | | | | | |

*Table 2. Limestone required to lift the pH of the top 10cm of soil to 5.2*
*Source* (Upjohn, Fenton, & Conyers, 2005)

## Bibliography


- ADAS Gleadthorpe Research . (2002). *Effect of Farm Manure Additions on Soil Quality and Fertility, Final Project Report.* UK.
- Aumann, C., & Fisher, P. (n.d.). Characteristics of non-living Soil Organic Matter Info leaflet. DPI.
- Aumann, C., & Fisher, P. (n.d.). Soil Health and Soil Organic Matter Info Leaflet. DPI.
- Batie, S. S., & Cox, C. A. (n.d.). *Health of our soils.* Retrieved from National Land and Water Information Service: http://www.agr.gc.ca/nlwis-snite/index_e.cfm?s1=pub&s2=hs_ss&page=7
- Bünemann, E. K., & McNeill, A. (2004). Impact of fertilisers on soil biota. *Soil Biology in Agriculture* (p. 64). Tamworth: NSW DPI.
- Carter, M. (2001). Organic matter and sustainability. *Sustainable Management of Organic Matter* , pp. 9-22.
- Chan, Y. (2004). Soil structure and soil biota: their interactions and implications on soil health. *Soil Biology in Agriculture* (p. 45). Tamworth: NSW DPI.
- Clark, G. D. (2007). Changes in chemical and biological properties of a sodic clay subsoil with addition of organic amendments. *Soil Biol. Biochem. 39* , 2806–2817.
- Delgado A, M. A. (2002). Phosphorus fertiliser recovery from calcareous soils amended with humic and fulvic acids. *Plant and Soil* , 277-286.
- Department of Primary Industries. (n.d.). *Victorian Resources online soils*. Retrieved from Victorian Resources online: http://www.dpi.vic.gov.au/dpi/vro/vrosite.nsf/pages/soil-home
- DPI, N. (n.d.). *http://www.dpi.nsw.gov.au/agriculture/resources/soils/structure/cec*.
- DPI, NSW. (2004). *How earthworms can help your soil*. Retrieved from www.dpi.nsw.gov.au.
- Edmeades, D. C. (2002). The effects of liquid fertilisers derived from natural products on crop, pasture, and animal production: A review. *Australian Journal of Agricultural Research 53(8) 965 - 976* , 965 - 976 .
- Edmeades, D. C. (June 2003,). The long-term effects of manures and fertilisers on soil productivity and quality: a review. *Nutrient Cycling in Agroecosystems, Volume 66, Number 2,* , 165-180(16).
- Gill, J., Sale, P., & Tang, C. (107 (2008)). Amelioration of dense sodic subsoil using organic amendments increases. *Field Crops Research* , 265–275.
- Guangdi Li, J. H. (2006). *MASTER — Earthworm numbers and microbial carbon concentration,Prime Facts sheet.* Retrieved from NSW DPI.
- Hollier, C. (2006, Sept). Small Farm: What is a healthy soil. *Agnotes* . DPI Victoria.
- Kirkegaard, J. (2004). Impact of management practices on soil biota activity on acidic clay loams in NSW. *Soil Biology in Agriculture* (p. 52). Tamworth: NSW DPI.
- Lake, B. (2000). Understanding soil pH. *Acid Soil Action* .
- Landcare. (n.d.). *Landcare - Issues - Soil Health*. Retrieved from Landcare Online: http://www.landcareonline.com

- Loveland P.J & Webb, J. (2003). Is there a critical level of organic matter in the soils of temperate regions: a review. *Soil & Tillage Research,* , 1-18. (Reference 47).
- Loveland P.J.and Webb, J. (1997). Critical Levels of Soil Organic Matter. *Literature Review* .
- National Soil Resources Institute. (2007). *Soil organic matter as a headline indicator of soil health.* Bedfordshire, UK: Cranfield University.
- Roget, D. K. (2004). Understanding soil biota and biological functions:Management of soil biota for improved benefits to cropproduction and environmental health. *Soil Biology in Agriculture* (pp. 7-14). Tamworth: NSW DPI.
- Sale, P. W. (1997). Reactive phosphate rock: an effective fertiliser for pastures in south east Australia? *Productive Pasture Systems: Grassland Society of Victoria Annual Conference, 38th, 24-26 June 1997, Proceedings,*, (pp. p141-148). Hamilton Vic.
- Schumann, B. (1999). The causes of soil acidity. *Acid soil action* .
- Schwenke, G. (2004). Soil organic matter, biological activity, and productivity:myths and realities. *Soil Biology in Agriculture* (p. 25). Tamworth: NSW DPI.
- Schwenke, G., & Jenkins, A. (2005). How to build organic matter in your soil. *Soil biology basics* . NSW DPI.
- Stokes, J., Cody, J., & Maheswaran, J. (2003). *A long-term study into compost applications for broadacre cropping.* DSE.
- SWEP Fact sheet. (n.d.). *Only five steps lead to soil health* .
- SWEP FACT SHEET. (n.d.). *Guidelines for Managing Plant nutrients in the soil* .
- Turner, N. (2004). Sustainable production of crops and pastures under drought in a Meditteranean environment. *Ann. Appl. Biol. 144,* , 139–147.
- Upjohn, B., Fenton, G., & Conyers, M. (2005). *AgFacts - soil acidity and liming.*
- Van Zwieten, L. (2004). Impacts of pesticides on soil biota. *Soil Biology in Agriculture* (p. 72). Tamworth: NSW DPI.
- Wikipedia. (n.d.). *Wikipedia*. Retrieved from www.Wikipedia.org.