Improving soil health

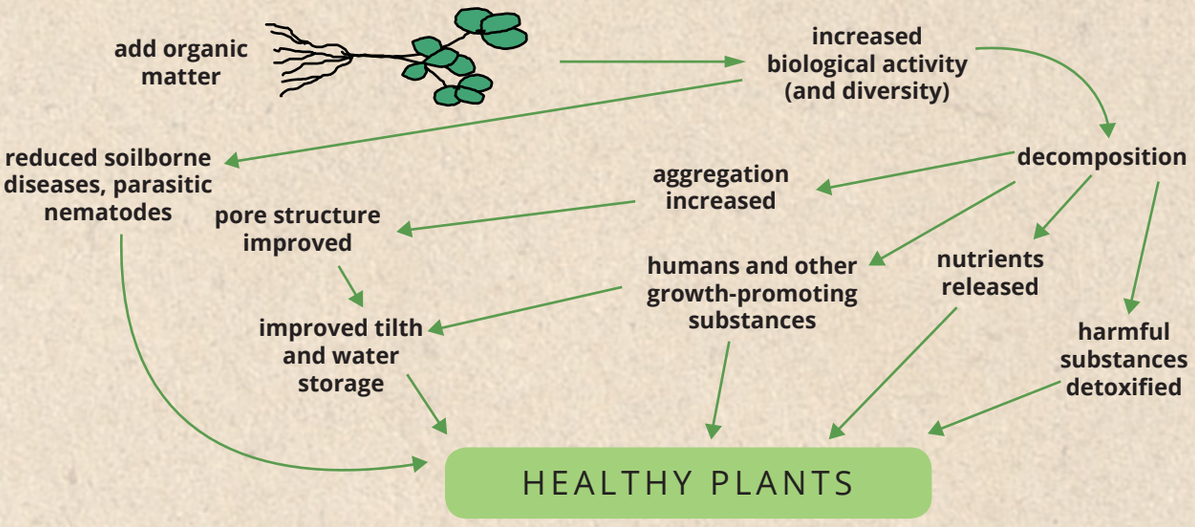
Chemical fertilisers can restore soil fertility quickly because the nutrients are available to the plants as soon as they dissolve in the soil. However they do not improve soil structure and there are other disadvantages to using them.

CA leads to a reduction in fertiliser use, with improved soil health and improved yields. Working with soil cover, crop rotation and cover crops is important to reach this goal.

We want to move from this ... **... to this**

There are many natural ways or products for improving soil health and fertility. Composting and manuring are common examples. This is where manure (dung) from animals and compost (humus) is added to the soil. Other examples include the use of liquid manures and brews, organic or eco-friendly fertilisers, green manuring and cover crops, nitrogen fixing trees, crop rotation, mixed cropping and earthworm farming.

Adding organic matter results in many changes in the soil.



A comparison between chemical fertilisers and natural soil fertility methods

Chemical Fertilisers: Disadvantages	Natural soil fertility methods: Advantages
✳ Chemical fertiliserfertilisers are quick-acting, short- term plant boosters. ✳ They can negatively impact on organic matter and soil structure ✳ Beneficial life in soil including earthworms are negatively impacted ✳ Chemical fertiliserfertilisers alter vitamin and protein content of certain crops making them more vulnerable to diseases. ✳ Growing plants often take up a lot of nitrates which makes growth soft and sappy and this is what pests love ✳ Over time essential elements can be "locked up" and are therefore not available to plants. This reduces the fertility of the soil and plants can be more susceptible to disease and pest attack. ✳ The activity of many soil organisms is inhibited. ✳ The soil tends to become acidic ✳ FertiliserFertilisers meet the basic nutrient needs of soil NPK but what about all the other elements? ✳ FertiliserFertilisers are inorganic. They are manufactured in factories and this is not sustainable and leads to climate change ✳ FertiliserFertilisers are expensive to produce and buy ✳ Chemical fertiliserfertilisers are easily leached out. This can lead to pollution of water sources	✳ We are working with nature and natural laws ✳ Natural methods and products of improving soil fertility work to address the issue as a whole - by increasing a variety of nutrient sources and levels, improving soil structure, water holding capacity and microbial activity (improving and encouraging life in the soil) ✳ When we use our own natural soil fertility methods, such as compost or cover crop seeds, we are in charge, we don't have to rely on anybody ✳ It is sustainable because we can keep making compost/use natural methods ✳ Nothing goes to waste and we recycle ✳ We use what we have or can afford ✳ It is cheaper to rely on and support natural processes than it is to buy external inputs and agrochemicals. ✳ Although it takes time for organic matter to decompose into humus and before the nutrients are released, these nutrients continueto improve soil fertility and soil structure for a long time. ✳ Nutrients are not as easily lost or leached out and they are recycled in the soil ✳ Crops produced in healthy soils are naturally healthy and show more resistance to disease and pests ✳ An increase in organic matter improves infiltration and soil water content and reduces the likelihood of erosion

Soil Nutrients

All living things are composed of the basic elements of the earth. Plants consist mainly of hydrogen, oxygen, carbon, nitrogen, phosphorus, potassium and smaller quantities of magnesium, sulphur and calcium as well as many other elements in very small amounts (these are called trace elements).

The following table summarises the nutrients that plants need to grow well.

Element	Common available form	Source
Needed in large amounts		
Carbon	CO_2	Atmosphere
Oxygen	O_2 and H_2O	Atmosphere and soil pores
Hydrogen	H_2O	Water in soil pores
Nitrogen	NO_3^- and NH_4^+	Soil
Phosphorus	$H_2PO_4^-$ and HPO_4^{-2}	Soil
Potassium	K^+	Soil
Calcium	Ca^{+2}	Soil
Magnesium	Mg^{+2}	Soil
Sulfur	SO_4^{-2}	Soil
Needed in small amounts		
Iron	FE^{+2} and FE^{+3}	Soil
Manganese	Mn^{+2}	Soil
Copper	Cu^+ and Cu^{+2}	Soil
Zinc	Zn^{+2}	Soil
Boron	H_3BO_3	Soil
Molybdenum	MoO_4^{-2}	Soil
Chlorine	Cl^-	Soil
Cobalt	Co^{+2}	Soil
Nickel	Ni^{+2}	Soil

Plants need three main kinds of nutrients:

- **Nitrogen (N) –** provides growth and green leaves;
- **Phosphorus (P) –** for healthy roots and fruit formation and provides hte plant with energy;
- **Potassium (K) –** for general health and healthy flowers and fruit and for providing plants with nice thick plant stems.

All three of these nutrients are found in healthy soils and good compost or manure. You can also increase the amount of these nutrients in the soil by mulching and crop rotations, especailly by mulching/rotating with leguminous crops like beans, peas, pigeon peas and Acacia (thorn tree leaves) or comfrey, using liquid manures and planting cover crops or green manures.

***Right:** A legume with root nodules that contain nitrogen fixing bacteria*

***Above:** A mulch formed from mazie stover after the maize has been harvested. This mulch will provide nutrients and improve soil structure and water holding capacity of the soil.*

Nitrogen (N)

Nitrogen is essential throughout the growing season. If the maize plant runs out of N at a critical time, ears are small and protein content is low. Kernels at the tip of the ear do not fill.

How do you know if your soil needs more nitrogen?

You will know your plants need nitrogen when the leaves are turning yellowish, instead of a strong bright green. There can be general yellowing of the older leaves and the whole plant may be light green.

How can you add nitrogen to your soil?

This element is found in most manures (cattle, sheep, pig, goat, chicken and rabbit). There is more nitrogen in chicken and goat manure. These must be dried before being used in the garden. Otherwise they can be too strong and 'burn' the plants.

Nitrogen can also be added to soil through **legumes**. These are plants that form nodules or little knots on their roots. These nodules 'fix' nitrogen from the air, so that the plant can take it up through its roots. There are microorganisms (bacteria) in the roots that help to 'fix' the nitrogen. After the roots of the plant die the nitrogen is released into the soil and can be used by surrounding or following plants.

The bacteria in the root knots bind free nitrogen from air in the soil and releases nitrogen after the plant dies

Examples of legumes that we often grow:

- Groundnuts
- Cowpeas
- Beans (including soybeans)
- Peas
- And fodder crops such as vetch, lucerne, clover and forage peas.

There are less common crops and also many long living plants and small trees that also fix nitrogen. Some examples are chick-peas, mung beans, lentils, pigeon peas, lab lab, velvet beans and tree lucerne.

Some legumes are grown only as green manures, and are not used for food. These include lab lab, velvet beans, lucerne, clover, hairy vetch and lupins. These give a lot more nitrogen to the soil than our food plants, because we flatten them onto the soil surface when they are still green. This is why we call them green manure cover crops. We can also plant our food crops in between these legumes through *intercropping*.

***Right:** Hairy vetch has fine leaves, and delicate purple flowers, as well as hairy stems as the name implies.*
http://www.fsl.orst.edu/forages/main.cfm?PageID=178&specid=41&use=Forage

Phosphorous

In maize production shortages of phosphorous interfere with pollination and kernel fill. Ears are small, often twisted and with undeveloped kernels.

How do you know if your soil needs more phosphorous?

You will know your plants need more phosphorous when they do not grow fast, as they should. The leaves may also start to show unusual red or pinkish colours, especially around the edges. If your plants are small and will not grow, even when compost is added, then you almost certainly have a severe phosphorous deficiency. This can also be caused by acidity in the soil.

How can you add phosphorous to your soil?

Many soils are poor in phosphorous. It is also a bit difficult to add phosphorous to the soil in an organic way, as most of the sources of phosphorous are tricky to work with. They include urine, bones, hair, feathers and blood. Usually we add these as ingredients to compost.

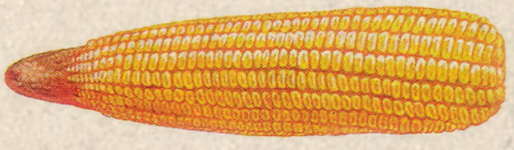
Natural rock phosphate can be added directly to the soil. This is also not easily available. Another good source of phosphorous is bone meal. You can usually buy this from an agricultural supply store – but it is not cheap.

One other way of adding phosphorous is to place bones in a fire, for a few hours. You can then grind them into a powder more easily. This powder can be spread on your garden beds or your compost heap.

The manure from animals grazing in areas where there is not much phosphorous will also have little phosphorous. You may need to bring in phosphorous in the form of chemical fertiliser. The usual source is called Superphosphate. Another chemical fertiliser known as MAP (Mono-ammonium Phosphate) can also be used. It is a good practice to correct any soil P deficiencies before starting with CA.

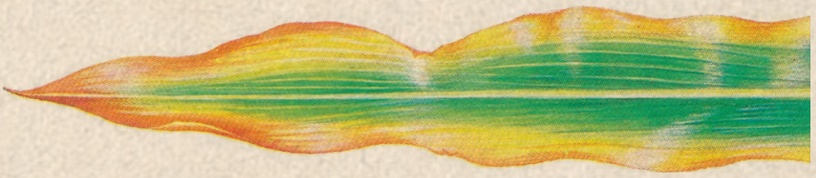
Potassium

Potassium shortages in maize shows up in the ears with poorly filled tips and loose, chaffy kernels.



How do you know if your soil needs more potassium?

You will know your plants need potassium when the plants become brittle and the leaf edges become brown and dry. When fruit does not form properly, you should also suspect a lack of potassium. Other signs can be hard to distinguish. One of these is a yellowing around the veins of the leaves. This could also be caused by diseases – so it can be difficult to know.



How can you add potassium to your soil?

Good sources of potassium are chicken manure and fresh woodash. Never use ash from coal, as this is very poisonous to the soil and plants. Another good source of potassium is a plant known as comfrey. This plant has large hairy leaves and grows in wet shady places. The leaves contain a lot of potassium. These can be used to mulch your vegetable beds and also to make liquid feeds for your plants.

The other elements or minerals needed in smaller quantities, such as Magnesium, Zinc and Iron, are found in most manure and in compost.

***Above:** Comfrey*
From: Useful Plants for Land Design, Pelum

Other important nutrients:

Calcium (Ca): Promotes plant fibre and strong plant tissue, promotes early root formation and seedling growth, aids in the uptake of nutrients, balances pH

Magnesium (Mg): Essential for the formation of Chlorophyll and formation of sugars, a carrier of phosphate and starches through the plant, promotes the formation of fats and oils, vital for healthy growth.

Sulphur (S): Increases root development, helps maintain the dark green colour, stimulates seed production, necessary for protein production, flavor and odour in many fruits and vegetables.

Micro or trace elements (nutrients needed in smaller quantities)

Iron (Fe): Is an oxygen carrier, enhances chlorophyll formation, metabolizes RNA, enhances green color of produce

Boron (Bo): Promotes early root formation and growth, improves health and sturdiness, increases yield and improves quality of fruits and vegetables. Improves the performance and availability of both calcium and silica.

Zinc (Zn): Essential for enzymatic reactions in cells and promotes plant growth.

Copper (Cu): Is needed for Chlorophyll production, catalyzes several plant reactions and necessary for making protein.

Manganese (Mn): Activates many metabolic reactions, increases absorption of calcium, magnesium and phosphorus, speeds germination and plant maturity.

Molybdenum (Mo): Enhances absorption of nitrogen by plants

Chlorine (Cl): Involved in photosynthesis and chlorophyll production, stimulates enzyme activity, helps control water loss and moisture stress.

Cobalt (C): Is needed in nodules of legumes for nitrogen fixing bacteria

Sodium (Na): Helps in water regulation and photosynthesis

These nutrients are important to plants for health and survival. They are equally important to animals and human health. This is because we get our nutrients from plants which take up essential nutrients from the soil. If our soil is healthy our plants benefit by being healthy and we in turn benefit from the variety of nutrients available.

Soil acidity

What is soil acidity?

Soil acidity can influence plant growth and limit crop yield. Minerals or nutrients needed by plants to grow are dissolved in the water inside the soil. This is a bit like salt or sugar dissolved in a glass of water.

Soil acidity is when the soil is “sour”. It is a bit like a glass of water that has vinegar dissolved in it. In places where it rains a lot, some of the minerals can be washed out of the soil. The soil then becomes acidic. The use of chemical fertiliserfertilisers over a long period of time can also make the soil acidic.

If there is too much acid in the soil, some minerals or plant food will dissolve too quickly and the plants cannot use them. Other minerals will not dissolve at all, so again, the plants cannot use them. Phosphorus is one of the minerals that cannot be used by plants when the soil is acidic – even if it is in the soil.

***Above:** An example of a maize field and the small stunted growth cause by soil acidity*

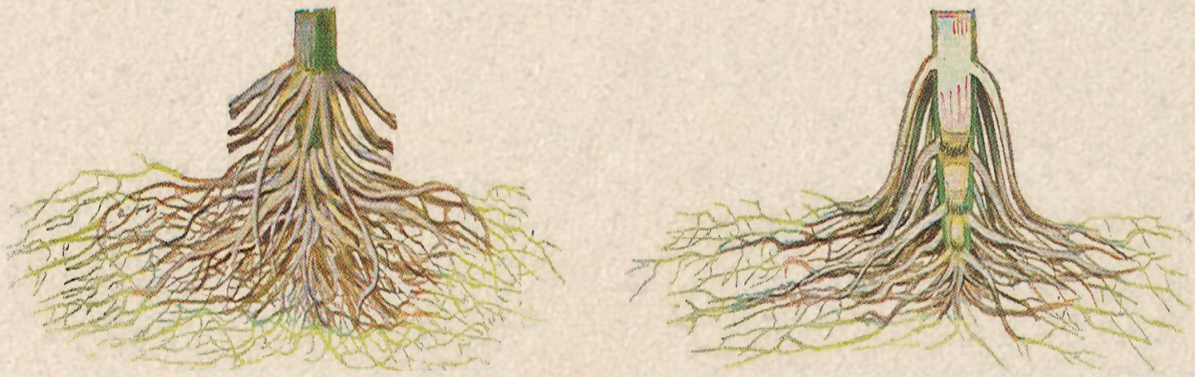
What causes acidity?

Acidic parent rock material, high rainfall and leaching of elements like calcium (Ca), magnesium (Mg), and phosphorous (P), decay of organic matter leading to release of organic acids into the soil, harvesting high yields (therefore removing plenty of Ca, Mg and P from the soil) and widespread use of nitrogen (N) fertilisers cause soil acidity.

How do you know if your soil is acidic?

You will know your soil is acidic if you provide compost or manure and water for your plants, but they do not grow. The plants remain small and stunted. This is a common problem.

Maize plants growing in acidic soil will have stunted shoots and leaves that are stubby and die back at tips. The leaf color is dull green with leaves and stems developing purple tints similar to phosphorus deficiency. Roots are short and stubby and lack fiber.



***Above:** (left) a maize root system grown in normal soil and (right) a maize root system grown in acidic soil*

pH is a measure of the soil's acidity or alkalinity. In water, it normally ranges from -1 to 14, with 7 being neutral. A pH below 7 is acidic and above 7 is alkaline. Soil pH is considered an important variable in soils as it controls many chemical processes that take place. It specifically affects plant nutrient availability by controlling the chemical forms of the nutrient. The optimum pH range for most plants is between 5.5 and 7.0. Soils below a pH (KCL) of 4,5 are considered to be very acidic/sour.

The primary cause of acid soil infertility is Aluminium toxicity and unavailability of existing Phosphorous (P) as well as Magnesium (Mg) and Molybdenum (Mo).

Acid saturation measures the total amount of exchangeable acidity or ions (cations). This differs for sandy and clay soils and thus a measure of acid saturation is given which indicates this for each type of soil. For growing maize acid saturation should not be higher than 20%

How will you solve the problem of acidity?

The only practical way of dealing with soil acidity is to add lime to the soil. The ideal agricultural lime is produced from limestone and/or dolomite rocks and consists primarily of calcium (Ca) and magnesium (Mg) carbonates. Lime can be bought and is a white powder, or grey granules. It can either be dug into your soil, at least as deep as the roots of the crop you are growing or be spread across the surface, or placed on the surface of the soil to be incorporated over time through natural processes.

Without the benefit of a soil sample analysis result a general rule of adding 1-2 tons/ha of lime every 2-3 years can be used.

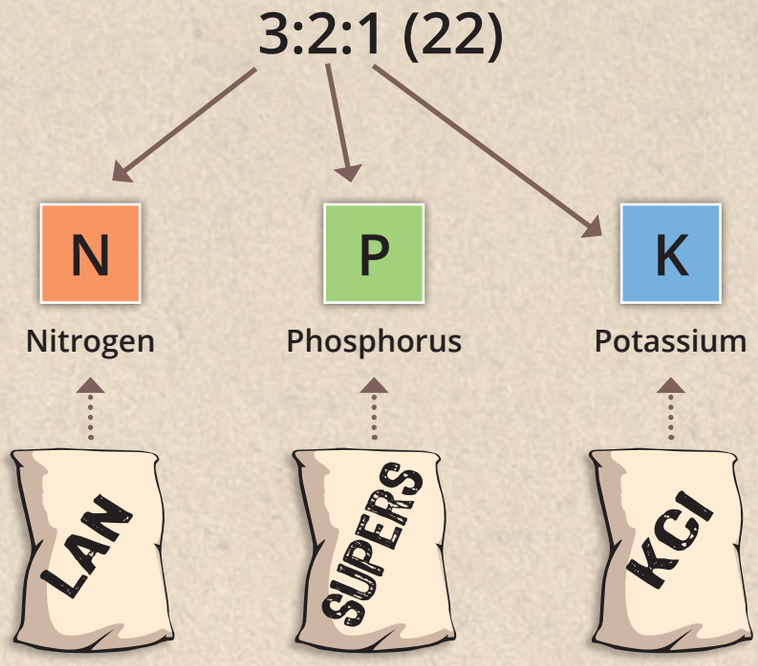
Usually lime is added 2 or 3 months before planting, as it is slow acting in the soil. If you add Lime at the same time as you are planting your crop, you will only see the main effect of the Lime in the next season. It is a good practice to correct soil acidity through the addition of lime before starting with CA.

Inorganic fertilisers

These are chemcials that you buy that contain the main plant nutrients or food in specific amounts.

The capital letters in brackets (N, P, and K) are called the chemical symbols. If you buy compound fertilisers, they may use these letters instead of writing out the name in full. An example is N:P:K or 3:2:1 which means the fertiliser contains 3 parts N to 2 parts P and 1 part K.

Compound fertiliser soil nutrient treatments



It is also possible to buy the fertilisers that supply a single nutrient at a time such as LAN, Supers and KCL.

There are many different fertilisers that can be bought that supply different amounts of the main nutrients. To know how much of each element you have to add, a soil sample analysis is done by a laboratory. These results will generally tell you how much of each nutrient is required.

It is also possible to use manure in stead of fertiliser and to use manure and fertiliser mixtures. Below is a table of common fertilisers and manures and the quantities of nutrients they provide.

Fertiliser Name	**Chemical composition**		
	%N	**%P**	**%K**
SINGLE FERTILISERS			
LAN (limestone ammonium nitrate) (28)	28	-	-
Urea (46) **more concentrated than LAN but more acidifying*	46	-	-
MAP (Monoammonium phosphate (33)	11	22	-
Single supers (10,5)	-	10,5	
KCL (Potassium Chloride) (50)	-	-	50
MANURES			
Cattle, horse	0,5	0,3	0,5
Improved Cattle	2,0	1,5	2,2
Goat	0,9	0,5	0,8
Improved Poultry	4	2,7	1,4
FERTILISER MIXTURES			
2:3:4(30)+0,5% Zn	6,7	10	13,3
3:2:1 (25) + 0,5% Zn	12,5	8,3	4,2

Notes to the table on the previous page:

***NOTE 1:** You will see that the singler fertilisers add much higher concentrations of the nutrients than the fertiliser mixtures. It is easier to be accurate with the single fertilisers, but you will need to 'mix' them on your farm if you are applying them at the same time. As the mixtures have already been mixed together, this step is removed.*

***NOTE 2:** Animal manures differ according to where the animals come from and what they have been eating. If their diet is poor, the quality of the manure will be poor and very few nutrients will be available. Animal manures contain a lot less of each nutrient per weight than fertilisers. They do however also have other benefits in the soil and improve organic matter content and soil health. Larger quantities of manure are required; generally in the order of 5 x more than fertiliser.*

***NOTE 3:** Improved manures, those that have been composted, provide much higher nutrient quantities.*

Here is an example of a fertiliser reommendation given for growing maize, for a soil sample around the Bergville area in KZN.

The following are fertiliser options (given in bags/ha) using DAP, MAP, Single Supers, 2:3:4 (38), KCl, LAN and urea for a specific soil sample.

***Soil sample yield target (t/ha) 4.0** – the amount of fertiliser added will increase the yield up to a point. So it is possible to decide on your target yield. There are a number of different combinations of fertilisers possible to give the correct amounts:*

- 4.0 bags/ha DAP; 1.0 bags/ha LAN or 0.6 bags/ha urea.
- 3.6 bags/ha MAP; 2.1 bags/ha LAN or 1.3 bags/ha urea.
- 7.6 bags/ha Single Supers (10.5%P); 3.6 bags/ha LAN or 2.2 bags/ha urea.
- 6.3 bags/ha 2:3:4(38); 1.7 bags/ha LAN or 1.0 bags/ha urea. The 2:3:4 would supply more than sufficient K.

Soil sample yield target (t/ha) 7.0

- 4.0 bags/ha DAP; 7.4 bags/ha LAN or 4.5 bags/ha urea.
- 3.6 bags/ha MAP; 8.6 bags/ha LAN or 5.2 bags/ha urea.
- 7.6 bags/ha Single Supers (10.5%P); 10.0 bags/ha LAN or 6.1 bags/ha urea.
- 6.3 bags/ha 2:3:4(38); 8.1 bags/ha LAN or 4.9 bags/ha urea. The 2:3:4 would supply more than sufficient K.

Soil sample yield target (t/ha) 10.0

- 4.0 bags/ha DAP; 10.3 bags/ha LAN or 6.3 bags/ha urea.
- 3.6 bags/ha MAP; 11.4 bags/ha LAN or 7.0 bags/ha urea.
- 7.6 bags/ha Single Supers (10.5%P); 12.9 bags/ha LAN or 7.8 bags/ha urea.
- 6.3 bags/ha 2:3:4(38); 11.0 bags/ha LAN or 6.7 bags/ha urea. The 2:3:4 would supply more than sufficient K.

From these recommendations it can be seen that to increase the target yield, more LAN is added and most likely as a top dressing when the maize is knee high. It is important to split the applications of N as it can be washed away and moves down into the soil profile where it may not be available for plants.

Micro dosing

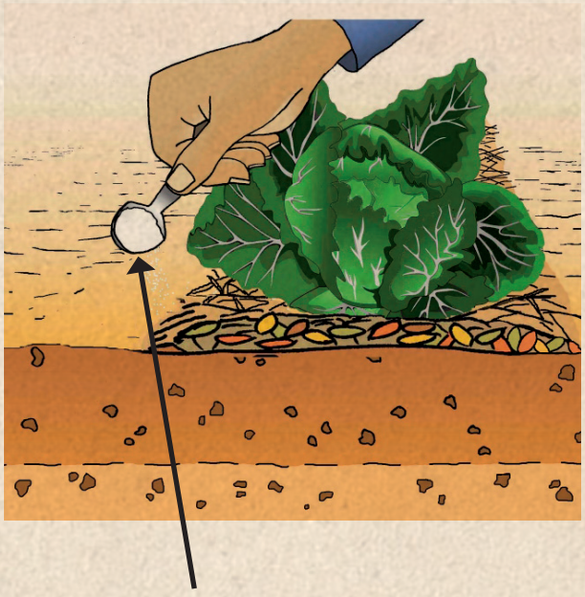
Micro dosing is a method of adding small quantities of fertiliser directly adjacent or next to plants where they can use it, rather than placing the fertiliser in bands or spreading it across the whole field. In this way much less fertiliser is used. This method is practised with CA. It is also recommended that fertiliser, manure combinations are used and that as little fertiliser as possible is used.

Below is a table that give general recommendations for use of fertiliser and manure when planting maize in a CA system.

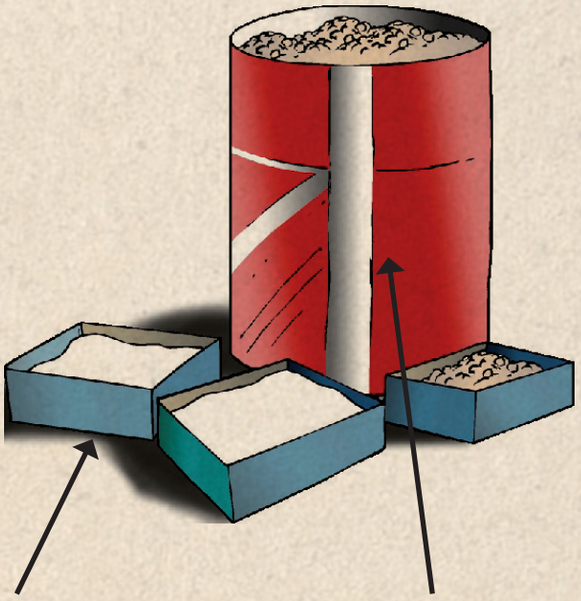
Fertiliser and Manure Quantities

Unless a soil sample specifically mentions the need for potassium (K), it is assumed that the higher clay soils (especially in KZN) as a rule do not need extra additions of potassium. This table represents a general recommendation for the midlands in KZN.

NAME	Element	Amount/ha	Amount/m2	Measuring
LAN (Basal)	28% N	100kg/ha = 355kg LAN	35.5g/m2 18 g /meter of row 9 g/planting basin	2 match boxes 1 matchbox ½ match box
LAN (top dress)	28%N	40kg/ha ~140kg LAN	10g/m2 5g/meter row 2.5g/planting basin	2 cooldrink bottle tops 1 cooldrink bottle top/ 1 teaspoon ½ cooldrink bottle top/ ½ teaspoon
Supers	10.5% P	40kg/ha = 380kg supers	39g/m2 20g/meter row 10 g/planting basin	2 match boxes 1 match box ½ matchbox
MAP (33) (supplies N and P)	11% N, 22% P	55 kg/ha P, 30kg/ha N = 250kg MAP	18g/ m2 8,3g/meter row 4,2g/planting basin	1 match box/ 1 table-spoon ½ match box 1 cooldrink bottle top/ 1 teaspoon
KCL	50% K	20kg/ha = 40 kg KCL	4g/m2 2 g/meter of row 1g/planting basin	1 cooldrink bottle top ½ bottle top (½ tea-spoon) ¼ bottle top (½ tea-spoon)
Lime		1ton/ha	1kg/m2 500g/meter row 250g/planting basin	1 large jam tin ½ large jam tin (or 1 normal food tin) ¼ large jam tin (½ food tin)
MANURE: Cattle/ goat	5kg/t N 2kg/t P 3kg/t K	10 tons/ha	10kg/m2 5kg/ meter row 2.5kg/planting basin	4 heaped spade fulls 2 spade fulls 1 spade full/ 4 large jam tins



1tsp/cool drink bottle top~2.5- 5g



1matchbox/ tablespoon~15-25g

1 large tin~400-900g

Measuring 1 metre using the length of a spade