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MANAGING SALINITY IN VEGETABLE CROPS

KEY MESSAGES

- ✔ **Salinity issues can appear in all major vegetable production areas; they can come and go depending on weather and changes in water quality.**
- ✔ **Salinity can occur naturally or as a result of management practices.**
- ✔ **Drought conditions can increase salinity in areas with natural salt in the soil profile due to:**
    - **lack of leaching rain**
    - **increased bore water salinity and evaporation from irrigation dams.**
- ✔ **Salt stress can look like water stress and nutrient deficiencies or toxicity.**
- ✔ **High electrical conductivity is not only a result of high chloride and sodium; nutrients, e.g. potassium, magnesium or sulphur, can contribute if in high concentrations in the soil solution.**
- ✔ **Manures, composts, organic fertilisers, recycled water and bore water can contain high levels of salts.**

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GOOD SALINITY MANAGMENT PRACTICES ON FARM

Manage irrigation

- **If possible, apply leaching irrigation with 'fresh' water (low or no salinity) to flush salts from the rootzone.** This will work best in well drained soils and if the groundwater (GW) level is not too high. High groundwater levels mean that drainage water can lift the GW level and may reach the rootzone. In heavier soils, chloride may leach, but too much sodium may stay behind in the rootzone as it 'binds' to clay particles. This can lead to sodicity issues. Drainage water should be able to leave the paddock via drainage systems in the landscape.
- If leaching salts from the rootzone is not the aim, make sure that irrigation water does match crop needs and soil moisture is always adequate; use soil moisture monitoring to achieve this.

Maintain good soil structure and organic carbon levels

- **Organic carbon levels should be maintained or increased to maintain or rebuild structure and drainage.** This is important because a saline soil often has poor structure and can be crusting or hard setting, especially when magnesium levels are also high. Building up soil carbon improves soil structure and permeability which enhances salt leaching, reduces surface evaporation and thus reduces salt accumulation in the surface layers.
- **Organic amendments like quality composts add organic carbon**. Apart from having a positive effect on structure, amendments also improve soil life. They improve nutrient cycling and availability. They encourage good crop establishment and root growth.
- If possible, **include cover crops into crop rotations**. Deep rooted cover crops would be good, but even a short-term cover crop break is preferable to bare soil. The greater the overall root mass of a cover crop, the better. Root mass is more important than growing large tops.
- **Use as little tillage as possible, especially via power implements; avoid unnecessary deep ripping.**
- **Use controlled traffic as much as possible.**
- **Apply low salt gypsum to reduce soil crusting and improve soil structure and drainage from the rootzone especially in high pH soils**; be careful not to increase electrical conductivity (EC) via overuse of gypsum. Gypsum is not very effective in sandy soils, concentrate on maintaining organic carbon.
- **Lime is effective in reducing soil crusting and improving soil structure and drainage from the rootzone in low pH soils**; a mix of gypsum and lime can give good results. Lime it is not effective in soils above pH 7.
- **Avoid bare ground** as much as possible to reduce loss of organic carbon and nitrogen through volatilisation and erosion. Leaving a saline soil fallow can increase salinity if evaporation of water from the soil is leaving salts behind. A cover crop can help to avoid this.

Figure 1: Stunted crop growth

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Manage crop nutrition

- **Manage the soil's nutrient status** - maintain satisfactory levels of nutrients and pH to promote a balanced status in the soil and to encourage good root growth. Monitor actual nutrient uptake via sap testing to be able to correct any deficiencies before they are visible.
- Under saline conditions calcium nitrate (with or without boron, depending on the crop), additional potassium (but not as muriate [the chloride form]) can be good fertiliser options. **Fertilisers** containing soluble calcium such as calcium thiosulphate can lessen the effects salinity has on crops and soils. Additional phosphorus is often needed for good crop establishment and growth.
- **Fertilisers can add to salinity** depending on how 'salty' they are. **The 'salt index' of a fertiliser is an indicator of 'saltiness'; it relates to its relative solubility. It is best to avoid fertilisers with a salt index greater than 100.** Table 4 provides the salt index of some common fertilisers. **Ask suppliers about the salt index of fertilisers you use.**
- **Acidifying fertilisers**, e.g. ammonium sulphate or urea, **should not be used on saline soils**.

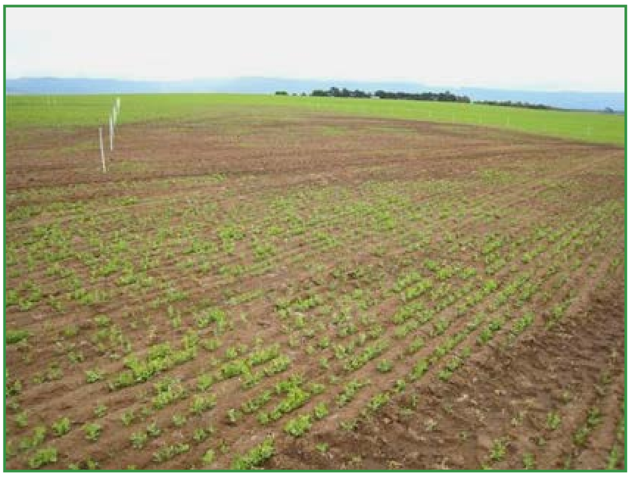

Figure 2: Bare area in new crop growth (salt scald)

- **Salinity suppresses uptake of nutrients through the roots**, especially calcium and potassium, but also phosphorus and boron. Plant nitrogen uptake may be affected as well. Depending on the value of the crop and the situation, foliar fertilisers can be used to supplement a soil-applied fertiliser program.
- **Decisions on fine tuning the types, timing, placement and rates of fertilisers should be based on soil and plant sap analyses. A dry tissue analysis may not be sensitive enough to show salinity effects on nutrient uptake, especially uptake of sodium and chloride.**

Farm scale management

- **Good drainage is essential** for farm scale salinity management so that salts can be washed out and taken away from the property as much as possible. The drainage water needs to be able to eventually drain to a ditch, stream or river so that it does not flow back onto the farm or affect neighbouring farms. It is also important to intercept any drainage water coming onto the property from other farms, if possible.
- In some cases, **it may be worth planting deep rooting shrubs or trees in lower lying, unproductive areas.** Plants with deep roots utilise more water and help to remove water from the soil profile. They assist in lowering the water table or maintaining it at a constant level to prevent salts rising to the soil surface through evaporation and capillary rise. If the soil is already quite saline, plantings must be done with tolerant trees or shrubs. Local assessment and advice and a landscape wide approach may be required.

WHY IS SALINITY BAD?

Salinity has different effects on different crops, some crops are more tolerant and will be less affected by increased soil salinity than others. Generally, salinity

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leads to poor crop establishment and growth, causing yield and quality losses.

Effects of salinity on vegetable crops

Salinity symptoms (salt stress) can look like water stress and nutrient deficiencies because salinity causes both. Usually, leaf margins yellow and die off because salts accumulate there due to transpiration. This makes the symptoms look similar to potassium deficiency. Plants are smaller and may die off early. Seedlings struggle to establish.

The best way to confirm salt stress is via testing the soil, water and plant sap.

The effect of salinity on plants is due to two main mechanisms.

1. **Reduced ability to take up water**

- Normally water uptake into plants is mainly passive, following a concentration gradient from lower to higher concentration. Plant sap is 'saltier' than the soil solution, therefore water 'flows' towards roots and is absorbed. Under saline soil conditions, the plant sap is less 'salty' than the soil solution and plants cannot take up water against the concentration gradient.

2. **Imbalanced nutrient uptake**

- Increased soil salinity may lead to a reduction in plant uptake of potassium, calcium, phosphorus, nitrogen and boron. This has been seen in plant sap test results. Potassium is important in regulating stomata closure in leaves. Reduced potassium uptake means that plants, while struggling to take up water due to salinity in the rootzone, will **also** lose it more easily through stomata.
- Naturally saline soils are often high in magnesium, which is a cation (a positively charged ion). Due to the greater concentration of magnesium there is further decreased uptake of other cations - calcium and potassium as well as ammonium (NH_4^+).
- Nitrate (NO_3), orthophosphate (PO_4^{3-}) and chloride (Cl^-) are negatively charged, and plants do not easily differentiate between them, especially between nitrate and chloride. When salinity is high, too much chloride is taken up by the plants, and nitrogen uptake may be low.

SALINITY THRESHOLDS FOR VEGETABLES

Tolerance to soil salinity for a range of vegetable crops

Table 2 (page 8 of this factsheet) shows published tolerances of some vegetable crops to soil salinity. It provides an average threshold for soil salinity as EC_{se}. If salinity goes above the threshold, yield losses are likely to occur without management interventions described earlier in this factsheet. The table lists EC_{se} threshold values for 10%, 25% and 50% yield loss.

To roughly convert EC_{se} to the $EC_{1:5}$ soil level given in most soil tests, multiply EC_{se} by 10 – read on for a more accurate conversion factor.

Tolerance to irrigation water salinity for a range of vegetable crops

- Table 3 shows salinity thresholds for irrigation water applied to different soil textures (sand, loam, clay). Generally, the coarser the soil texture, the higher the tolerance to saline water because coarsely textured soils drain well. The table lists EC_w threshold average values for 10%, 25% and 50% yield loss due to irrigation water salinity (if no management intervention occurs). Generally, well drained soils are affected less by saline water than poorly drained soils.

Tables 2 and 3 are a guide only; actual responses to salinity will vary, depending on growing conditions and crop management.

Read on for more background information.

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WHAT IS SALINITY

Salts are crystalline compounds consisting of a cation (a positively charged ion) and an anion (a negatively charged ion).

Salinity refers to the 'saltiness' of soil or water. The higher the concentration of water-soluble salts in the soil solution or in water, the higher the salinity. Sodium and chloride, the elements of common salt, are the most damaging salts to plant health. The term 'salinity' used in agronomic terms usually refers to an excess of sodium and chloride in the soil or water.

What is the difference between salinity and sodicity?

Sodicity is a term referring to the amount of sodium (Na) held in a soil on exchange sites of clay minerals and organic matter. Sodium is a cation just like calcium (Ca), magnesium (Mg), potassium (K) and hydrogen (H). Different to salinity, chloride is not involved in sodicity. Soil sodicity starts to have a negative influence on crop growth when more than 6% of the soil cations are sodium. The proportion of sodium of the cation exchange capacity (CEC) is called 'Exchangeable Sodium Percentage' or ESP. Draining of saline soils can result in chloride being removed and sodium being left behind, turning the soil from saline to sodic.

Sodic soils have poor structure, they 'slump'. They are hard setting when dry and sticky when wet. They are also prone to erosion. The term 'dispersion' or 'dispersive soil' describes this condition. This fact sheet does not include information on managing sodic soils; the focus is on managing salinity.

WHAT CAUSES SALINITY?

On vegetable farms, salinity issues occur mainly in dry years when there is a lack of flushing rain and bore or dam water salinity increases due to a lack of fresh water replenishment. In some areas salinity can be due to changes in the amount of irrigation water used and drainage occurring in the landscape.

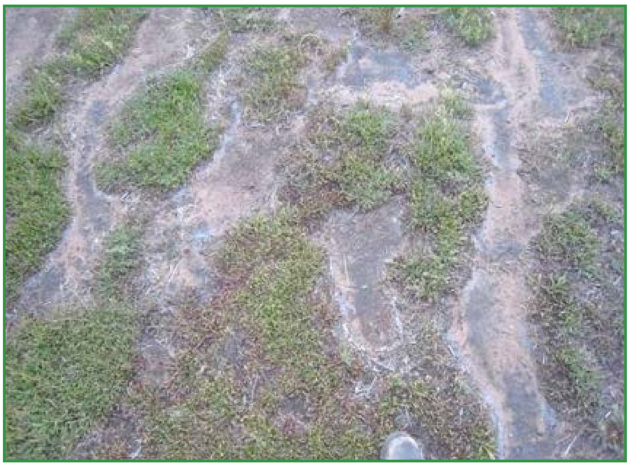

Figure 3: Salt crusting

Saline soils are either naturally occurring in the landscape (**primary salinity**) or have developed from natural salt deposits that are in deeper soil layers or salty groundwater as a result of land-use changes and management practices (**secondary salinity**). These practices often include removal of trees and other vegetation from the landscape and high input of irrigation water. **Secondary salinity can occur in dryland or irrigation situations**. The reduction in water uptake by vegetation, often combined with more water input in an entire region can bring salty water closer to the soil surface and ultimately into the rootzone. Land use and management changes often lead to perched water tables over impermeable subsoils. Therefore, salinity is first evident in lower lying areas of a paddock or low-lying areas in the landscape.

Salinity in water, e.g. in bore water where salt deposits occur somewhere in the profile, is naturally occurring. Saline dam water can be induced through land use change described above and in dry years due to evaporation and lack of fresh water influx. Wastewater is usually saline.

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HOW CAN SALINITY BE IDENTIFIED?

Salinity can be identified in a variety of ways, including:

- **visual** identification from plant and soil symptoms e.g. salt scalds, surface crusting of salt or in poor areas within crops often in lower lying areas of a paddock including yield losses, stunted plants or 'burnt' leaves
- the presence of salinity **indicator plant species** in affected areas (these vary from region to region)
- **measurement** of the electrical conductivity (EC) of soil and/or water samples
- **a plant sap analysis** which includes sodium and chloride in the testing suite; the analysis can identify salinity issues and effects on other nutrients before serious crop damage occurs.

Salinity in the landscape

Once salinity is obvious in paddocks and the landscape, the economic damage to crops can be significant. It is therefore important to detect early warning signs via soil, water and plant testing. Figures 1 to 3 show examples of salinity in the landscape and the effect on crops.

SALINITY MEASUREMENT

Soil salinity is generally measured by determining the electrical conductivity (EC) of a 1 in 5 soil-water or calcium chloride suspension. Laboratory analyses can be used to determine the levels of individual salts, especially chloride and sodium, the most damaging salts to plant and soil health.

Figure 4: Hand-held conductivity meter

The EC measurement will pick up all salts in the water or soil solution, e.g. including those from fertilisers. Excessive use of gypsum can also lead to high EC values. If a soil test shows high EC, it is worth checking chloride levels. If they are in the normal range, the high EC is caused by other elements e.g. magnesium or sulphur.

The predominantly used unit of measurement for EC is deciSiemens per metre (dS/m). 1 dS/m is the same as 1 milliSiemens per centimetre (mS/cm) or 640 ppm. Table 1 shows all conversions between different measurement units for salinity.

The pH reading of non-saline soil in calcium chloride is normally about 0.5-0.8 units lower than that recorded in water. In saline soils, both pH values are similar.

Table 1: Average conversion factors for EC measurements

dS/m	mS/cm	millimho/cm	mS/m	ppm or mg/L	µS/cm	µmho/cm
1	1	1	100	640	1000	1000
0.001	0.001	0.001	0.1	6.4	1	1
0.00156	0.00156	0.00156	0.156	1	1.56	1.56

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How to determine EC in soils and water

DIY testing

EC can be measured using a hand held conductivity meter (Figure 4) or through laboratory analysis. If using a hand held meter, it is important to calibrate it regularly! In water the probe can be used without any sample preparation. Salinity in soils is measured in a mix of 1 part soil to 5 parts water. It is best to air or microwave dry the soil and use filtered rainwater or bottled water in a clean jar. Let the mix settle for a while before measuring the water above the settled soil.

This gives you a measurement for $EC_{1:5}$. You need to convert it to EC_{se} if you want to compare the measurements to salinity tolerances in Table 2. Conversion factors are in the table in Figure 5.

Using a hand held meter is great for monitoring fluctuations in irrigation water salinity. Keep a log of your measurements.

Lab testing

There are three ways that EC can be reported by a lab - $EC_{1:5}$, EC_{se} (EC_e) for soil and EC_w for water.

Soil test reports

- **$EC_{1:5}$** – This measurement is commonly used for soil samples and reports the conductivity reading of a suspension of **1 part soil to 5 parts water** (deionised or distilled).
- **EC_{se}** – is the EC of the **s**aturation **e**xtract (or just **e**xtract - EC_e). This measurement from a soil paste removes the effect soil texture has on a soil water solution as used for $EC_{1:5}$. EC_{se} can be calculated by multiplying the $EC_{1:5}$ reading by a soil texture conversion factor. EC_{se} is used to report tolerances to soil salinity.

Figure 5 shows multiplication factors used for different soil textures. The reason texture needs to be considered is that clay particles will buffer (hold onto) the salts in the soil water more than sand, due to their greater exchange capacity. Plants growing in a saline clay soil of an $EC_{1:5}$ reading of 1 dS/m will be less affected by the salts than a plant in a sandy soil with an $EC_{1:5}$ reading of 1 dS/m.

Water test reports

- **EC_w** – is the EC of **w**ater. It is a direct EC measurement of salinity for water sources.

$EC_{1:5}$ lab test result x

Soil texture	Multiply by to convert to EC_{se}
Sands	17
Sandy loams	14
Loams	9.5
Clay loams and light clays	8.6
Medium and heavy clays	6.7

= EC_{se} published data on crop salinity tolerances

Figure 5: How to convert $EC_{1:5}$ to EC_{se} using figures from Tenison et al. (2014)

Most published data on crop tolerances to soil salinity are reported in EC_{se} (see Table 5). If a soil test report provides $EC_{1:5}$ only, it is important to convert the reading to EC_{se} to check against crop tolerances (using the equation in Figure 5).

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Table 2: Tolerance of vegetables to salinity in soils

Common name	Tolerance to salinity	Average root zone soil salinity threshold (EC_{se} [dS/m])	EC_{se} threshold for crop losses (dS/m)		
			10%	25%	50%
Asparagus	tolerant	4.1	9.1	16.6	29.1
Artichoke	moderately tolerant	6.1	7.0	8.3	10.4
Beet, garden	moderately tolerant	4.0	5.1	6.8	9.6
Rosemary	moderately tolerant	4.5			
Zucchini	mod. tolerant	4.7	5.8	7.4	10.0
Broadbean	mod. sensitive	1.5	2.6	4.2	6.8
Broccoli	mod. sensitive	2.8	3.9	5.5	8.2
Cabbage	mod. sensitive	1.8	2.8	4.4	7.0
Capsicum	mod. sensitive	1.5	2.2	3.3	5.1
Cauliflower	mod. sensitive	2.5			
Celery	mod. sensitive	1.8	3.4	5.8	9.9
Cucumber	mod. sensitive	2.5	3.3	4.4	6.3
Eggplant	mod. sensitive	1.1	2.5	4.7	8.3
Kale	mod. sensitive*	6.5			
Lettuce	mod. sensitive	1.3	2.1	3.2	5.1
Onion (seed)	mod. sensitive	1.0	2.3	4.1	7.3
Pea	mod. sensitive	2.5	4.3	5.8	8.1
Potato	mod. sensitive	1.7	2.5	3.8	5.9
Radish	mod. sensitive	1.2	2.0	3.1	5.1
Spinach	mod. sensitive	2.0	3.3	5.3	8.6
Squash		2.5			
Squash, scallop	mod. sensitive	3.2	3.8	4.8	6.3
Sweet corn	mod. sensitive	1.7	2.5	3.8	5.9
Sweet potato	mod. sensitive	1.5	2.4	3.8	6.0
Tomato	mod. sensitive	2.5	3.5	5.0	7.6
Turnip	mod. sensitive	0.9	2.0	3.7	6.5
Bean	sensitive	1.0	1.5	2.3	3.6
Carrot	sensitive	1.0	1.7	2.8	4.6
Onion (bulb)	sensitive	1.2	1.8	2.8	4.3

"These data serve only as a guideline to relative tolerances among crops. Absolute tolerances vary, depending upon climate, soil conditions, and cultural practices." - Ayers and Wescot (1985)

* Estimated sensitivity - this is the published data, from personal observation kale is probably closer to broccoli in its tolerance to salinity

Adapted from deHayr and Gordon (2006) and Ayers and Westcot (1985)

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Table 3: Tolerance of vegetables to salinity in irrigation water

Common name	Tolerance to salinity	Average root zone soil salinity threshold (EC_{se} [dS/m])	EC_w threshold for crops growing in			EC_w threshold for crop losses (dS/m)		
			sand	loam	clay	10%	25%	50%
Asparagus	tolerant	4.1	5.2	3	1.7			
Artichoke	mod. tolerant	6.1						
Beet, garden	mod. tolerant	4.0	6.5	3.7	2.1	3.4	4.5	6.4
Rosemary	mod. tolerant	4.5	5.7	3.3	1.9			
Zucchini	mod. tolerant	4.7	7.3	4.2	2.4	3.8	4.9	6.7
Broadbean	mod. sensitive	1.5	3.3	1.9	1.1	1.8	2.0	4.5
Broccoli	mod. sensitive	2.8	4.9	2.8	1.6	2.6	3.7	5.5
Cabbage	mod. sensitive	1.8	3.5	2	1.2	1.9	2.9	4.6
Capsicum	mod. sensitive	1.5	2.8	1.6	0.9	1.5	2.2	3.4
Cauliflower	mod. sensitive	2.5	3.2	1.8	1.1			
Celery	mod. sensitive	1.8	4.3	2.5	1.4	2.3	3.9	6.6
Cucumber	mod. sensitive	2.5	4.2	2.4	1.4	2.2	2.9	4.2
Eggplant	mod. sensitive	1.1	3.2	1.8	1.1			
Kale	mod. sensitive*	6.5	8.2	4.7	2.7			
Lettuce	mod. sensitive	1.3	2.7	1.5	0.9	1.4	2.1	3.4
Onion (seed)	mod. sensitive	1.0						
Pea	mod. sensitive	2.5	3.2	1.8	1.1			
Potato	mod. sensitive	1.7	3.2	1.8	1.1	1.7	2.5	3.9
Radish	mod. sensitive	1.2	1.5	0.9	0.5	1.3	2.1	3.4
Spinach	mod. sensitive	2.0	4.2	2.4	1.4	2.2	3.5	5.7
Squash		2.5	3.2	1.8	1.1			
Squash, scallop	mod. sensitive	3.2	4.8	2.7	1.6	2.6	3.2	4.2
Sweet corn	mod. sensitive	1.7	2.2	1.2	0.7	1.7	2.5	3.9
Sweet potato	mod. sensitive	1.5	3	1.7	1	1.6	2.5	4.0
Tomato	mod. sensitive	2.5	3.5	2	1.2	2.3	3.4	5.0
Turnip	mod. sensitive	0.9	2.5	1.4	0.8	1.3	2.5	4.3
Bean	sensitive	1.0	1.9	1.1	0.6	1.0	1.5	2.4
Carrot	sensitive	1.0	2.2	1.2	0.7	1.1	1.9	3.0
Onion (bulb)	sensitive	1.2	2.3	1.3	0.8	1.2	1.8	2.9

"These data serve only as a guideline to relative tolerances among crops. Absolute tolerances vary, depending upon climate, soil conditions, and cultural practices." - Ayers and Wescot (1985)

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Table 4: Salt index of fertiliser materials and soil amendments

Fertiliser materials	Total Nitrogen (N) %	Total Phosphorus (P) %	Total Potassium (K) %	Total Sulphur (S) %	Salt index*
Nitrogen materials					
Ammonium nitrate	33.5–34				104
Sodium nitrate	16				100
Ammonium sulphate	21			24	88.3
Urea	45–46				74.4
Calcium nitrate (CAN)	15.5				65.0
Diammonium phosphate (DAP)	16–18	20–21			29.2
Monoammonium phosphate (MAP)	11	21			24.3
Phosphate materials					
Single superphosphate (SSP)		7.9–8.7		12	8.4
Triple superphosphate (TSP)		20		1	10.1
Phosphoric acid		23			
Potassium materials					
Potassium chloride (muriate of potash)			50		116
Potassium nitrate	13		36.5		69.5
Potassium sulphate			41.5–44	18	42.6
Sulphate of potash magnesia (K-MAG)			22	22	43.4
Sulphur materials					
Ammonium thiosulphate (ATS)	12			26	90.4
Ammonium polysulphide	20			40	59.2
Gypsum				17	8.1
Magnesium oxide					1.7
Magnesium sulphate				14	44
Miscellaneous					
Lime (calcium carbonate)					4.7
Dolomite (calcium/magnesium carbonate)					0.8
Manure / composts^	variable	variable	variable	variable	approximately 110

*Salt index - comparison of equal weights of materials, compared to sodium nitrate having a nominal value of 100

^ depending on origin - guidance only - composts should be tested

Adapted from Fernandez (2010), A&L Great Lakes Laboratories (2002) and Ayers and Westcott (1985)

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WHAT EC RANGE IS APPROPRIATE FOR SOILS AND WATER

From EC measurements, soil salinity classes can be applied to land areas or paddocks. This contributes to understanding what crops can be grown and the different management practices required to manage a specific soil due to its salinity class (see Table 5).

Table 5: EC_w and EC_{se} values of soil salinity classes

	Class 1	Class 2	Class 3	Class 4	Class 5
Water	low	medium	high	very high	extreme
EC_w	0 - 0.28	0.28 - 0.8	0.8 - 2.3	2.3 - 5.5	over 5.5
Soil*	low	moder-ate	high	extreme	
EC_{se}	0 - 2	2 - 6	6 - 15	over 15	

* Make sure to multiply the $EC_{1:5}$ by the soil texture factor to come up with the EC_{se} figure when checking crop tolerances.

Table 6 lists the desirable ranges of EC, sodium (Na) and chloride (Cl) in soil, plant sap and water.

The chloride level is a reliable salinity indicator. EC may be high in non-saline soils due to high levels of electrolytes other than Cl and Na (e.g. S, Mg, K).

Table 6: Desirable ranges of EC, sodium (Na) and chloride (Cl) in soil, plant sap and water

What to monitor	Desirable range		
	Soil	Plant sap	Water
Electrical conductivity	<0.2 dS/m ($EC_{1:5}$)	N/A	<0.65 dS/m
Sodium (Na)	<90 mg/kg	<200 ppm	<74 ppm or <3.2 meq/L
Chloride (Cl)	<200 mg/kg	<2000 ppm	<200 ppm

1 ML of water with an EC_w of 1 dS/m contains about 640 kg of salts (NSW DPI [2016]).

We would like to acknowledge the valuable contributions of Bruce Scott (EE Muir) and Julie Finnigan (Serve-Ag) to the development of this factsheet. Thank you to Julie Finnigan for use of her photos.

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