Department of Primary Industries
primefact

Salinity tolerance in irrigated crops

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Agriculture NSW Water Unit

Different crops can tolerate different levels of salinity in irrigation water. Many factors influence a plant's tolerance to salinity, including:

- climate – particularly the amount and seasonality of rainfall to leach salts from soils
- soil types and drainage characteristics within the root zone, which influence leaching and salt accumulation
- whether the plant is a halophyte (salt-tolerant) or glycophyte (salt-sensitive).

Other factors include rootstock or variety, irrigation method (surface or flood, overhead sprinkler, drip), stage of plant growth and irrigation management.

Salinity tolerances of some commonly irrigated crops and forage plants in NSW are grouped into the following categories:

- vegetable crops (Table 1)
- fruit and nut crops (Table 2)
- field crops (Table 3)
- forage crops, pasture grasses and clovers (Table 4).

The salinity tolerance levels shown in the tables are indicative only, and refer to crops growing in moderate- to slow-draining soils (the drainage characteristic occurring most frequently in soils used for irrigation) in an NSW inland climate. Crop salinity tolerances can be up to 50% higher than shown below in well-drained soils such as deep sandy loams where percolation and leaching are rapid. In very slow-draining soils, such as the medium to heavy clays of the rice growing regions, tolerances can be down to about half the levels shown.

If irrigation water is saline, a leaching requirement (additional water applied to drain past the root zone) is desirable to avoid excess salt accumulation in the plant root zone.

Establishing salinity tolerance

Salinity tolerances are mostly adapted from the *Australian and New Zealand guidelines for fresh and marine water quality* (ANZECC & ARMCANZ, 2000a; 2000b). In some cases, research findings (published and unpublished/personal communication) by Australian scientists were identified in previous publications and some have been included. Notes accompanying the tables provide a description or recommend some caution where a supporting reference was not available[i].

Measuring salinity in water

Salinity in irrigation water is measured by electrical conductivity ECw (see *How salinity is measured*). **Salinity levels in the following tables are expressed as deciSiemens per metre (dS/m) at 25 °C.**

Some publications express salinity as EC units (generally as microSiemens per centimetre, µS/cm) or as total dissolved solids (TDS) in mg/L (the same as parts per million). The conversion factor is:

1 dS/m = 1000 EC (or µS/cm) = approximately 640 mg/L (or ppm)

Note that one megalitre at ECw of 1 dS/m contains about 640 kg of salts.

Table 1. Vegetable crops — water salinity tolerance (ECw)

This table indicates the yield reductions that could be expected when various vegetable crops are irrigated with saline water and grown in moderate- to slow-draining soils.

Vegetable crop	No reduction (dS/m)	10% reduction (dS/m)	25% reduction (dS/m)
Zucchini	3.1	3.8	4.9
Garden beet	2.6	3.4	4.5
Broccoli	1.8	2.6	3.7
Cucumber	1.7	2.2	2.9
Tomato	1.5	1.9	2.4
Cantaloupe/rockmelon	1.5	2.4	3.7
Watermelon [1]	1.5	2.4	3.8
Spinach	1.3	2.2	3.5
Cabbage	1.2	1.9	2.9
Celery	1.2	2.3	3.8
Broad bean	1.1	1.7	2.8
Potato	1.1	1.7	2.5
Sweet potato	1.0	1.6	2.5
Capsicum [2]	1.0	1.5	2.2
Sweet corn	1.1	1.7	2.5
Lettuce	0.9	1.4	2.1
Onion [3]	0.8	1.2	1.8
Radish [4]	0.8	1.3	2.1
Eggplant	0.7	1.7	3.1
Carrot	0.7	1.1	1.8
Bean	0.7	1.0	1.5
Turnip	0.6	1.3	2.4

Note: The salinity tolerance of seedlings of most vegetable plants is likely to be less than the levels shown.

[1][3][4]There is no reference to salinity tolerance for these crops in the ANZECC & ARMCANZ (2000b) guidelines. The values presented in Table 1 are from Table 5 of the crop tolerance tables from WA Department of Agriculture & Food (Neil Lantzke, Tim Calder and John Burt).

Note: Salinity tolerance values provided by WA DA&F are for loam soils [leaching fraction presumed to be ANZECC & ARMCANZ (2000b; equation 4.1) value for loamy soil of 0.33], rather than values for a moderate-to-slow draining soil generally provided in this table (0.3). The results for onion[3] and radish[4] are consistent with research presented in FAO (1999) *FAO61: Agricultural drainage management in arid and semi-arid areas,* and Maas (1984).

[2]**Capsicum:** The salinity tolerance provided is consistent with that for 'pepper' in the ANZECC & ARMCANZ (2000b) guidelines.

Table 2. Fruit and nut crops – water salinity tolerance (ECw)

This table indicates the indicate the salinity concentrations at which various percentage yield reductions will occur when various fruit and nut crops are irrigated with saline water and grown in moderate- to slow-draining soils.

Fruit and nut crop	No reduction (dS/m)	10% reduction (dS/m)	25% reduction (dS/m)
Fig [1]	2.8	2.53	na
Date	2.6	4.6	7.5
Olive [1]	2.6	2.5	na
Peach [2]	2.1	2.5	3.0
Grapefruit	1.2	1.6	2.2
Walnut [3]	1.1	1.6	na
Orange	1.1	1.5	2.2
Apricot	1.1	1.3	1.8
Grape	1.0	1.7	2.7
Almond	1.0	1.4	1.9
Plum	1.0	1.4	1.9
Boysenberry	1.0	1.3	1.7
Avocado	0.9	1.2	1.6
Pear [1]	0.7	1.5	na
Prune	0.7	na	na
Apple	0.7	1.0	1.6
Raspberry [1]	0.7	0.9	na
Strawberry	0.7	0.9	1.2
Lemon [4]	1.0	1.5	2.3

Note: Variety of rootstock may have a bearing on salinity tolerance of some fruit trees.

na = not available.

[1] Figures for 10% reduction for fig, olive, pear, and raspberry are from Table 6 of the crop tolerance tables from WA Department of Agriculture & Food (Neil Lantzke, Tim Calder and John Burt)

[2] Figures provided for peach in Table 6 of the crop tolerance tables from WA Department of Agriculture & Food (Neil Lantzke, Tim Calder and John Burt) are more conservative (1.1 dS/m 'no reduction', 1.3 dS/m '10% reduction', and 1.8 dS/m '25% reduction').

Note: Salinity tolerance values provided by WA DA&F are for loam soils [leaching fraction presumed to be ANZECC & ARMCANZ (2000b; equation 4.1) value for loamy soil of 0.33], rather than values for a moderate- to slow-draining soil generally provided in this table (leaching fraction factor of 0.3).

[3]There is no reference to salinity tolerance for walnut in the ANZECC & ARMCANZ (2000b) guidelines. The value presented in Table 2 for no reduction is consistent with information presented by DeHayr, *et al.* (1997) (Queensland DNR Water Facts W55). The value for 10% reduction is from an unreferenced source and should be considered with caution.

[4]Values for lemon are consistent with Cerda *et al. (*1990) presented in FAO (1999). Value previously presented in Table 2 (0.7 dS/m for no reduction) was based on ANZECC 2000b (ECse for no reduction only). Results may be influenced by rootstock for grafted lemons.

Table 3. Field crops — water salinity tolerance (ECw)

This table indicates the yield reductions which could be expected when various field crops are irrigated with saline water and grown in moderate-to-slow draining soils.

Field crop	No reduction (dS/m)	10% reduction (dS/m)	25% reduction (dS/m)
Barley	5.3	6.6	8.6
Cotton [1]	5.1	6.4	8.3
Sugar beet	4.6	5.7	7.4
Grain sorghum [2]	4.5	4.9	5.5
Canola [3]	4.3	7.3	na
Safflower	4.3	na	na
Wheat [4]	4.0	4.9	6.3
Sunflower	3.6	3.9	4.3
Oats	3.3	3.6	4.1
Soybean [5]	3.3	3.6	4.1
Peanut [6]	2.1	2.3	2.7
Sesbania	1.5	2.5	3.9
Sugarcane	1.1	2.2	3.9
Faba bean	1.1	1.7	2.8
Linseed/flax	1.1	1.7	2.5
Maize	1.1	1.7	2.5
Rice [7]	1.0	1.3	na
Cowpea (vegetative) [8]	0.9	1.3	2.0
Beans (field)	0.7	1.0	1.5

Notes: na = not available.

During the early seedling stage of the most tolerant crops, ECw should not exceed 3.0 dS/m.

Salinity tolerances can vary between crop varieties and field conditions compared with those presented in Table 3.

[1]**Cotton:** Yield reductions with adult cotton begin at 5.1 dS/m ECw in saline solution trials, but as little as 1.0 dS/m can affect seedlings in moderate to slow draining soils. Experience in northern NSW indicates that yields decline rapidly after the initial threshold is reached. An alternative 'no yield reduction' level of 1.7 dS/m has been used as a tolerance level for the average for the growing season in moderate- to slow-draining soils in previous DPI publications (source reference unknown). Cotton grown on slow-draining soils in northern NSW, with higher existing root zone salinity levels (ECse) and surface irrigation systems may have a lower 'no yield reduction' level due to the effects of soil sodicity.

[2]**Grain sorghum:** Daniells et al. (2001) found a 50% yield reduction in grain sorghum grown on sodic soils at average root zone salinity levels (ECse) of 2.8 dS/m, which is significantly lower than the 9.9 dS/m for the 50% yield reduction presented in Table 9.2.10 of the ANZECC & ARMCANZ (2000b) guidelines. Calculating the 'no reduction' level and '10% reduction level from Daniells et al. (2001) would give ECw values of 0.9 dS/m and 1.1 dS/m, respectively.

[3]**Canola:** There is no reference to salinity tolerance for canola in the ANZECC & ARMCANZ (2000b) guidelines. Values presented in Table 3 are based on research for *Brassica napus* L. by Francois (1994a) presented in FAO (1999). Values previously presented in Table 3 (4.3 dS/m for no reduction, and 7.3 dS/m for 10% reduction) were from an unreferenced source and should be considered with caution.

[4]**Wheat:** Durum wheat is less salt tolerant than bread wheat.

[5]**Soybean:** Tolerance of soybeans is proposed to be significantly lower, if they have never before been grown in the field (insufficient volume of suitable strain of *Rhizobium* to inoculate roots). The source reference for this information is unknown, and it is presumed most soybeans would be grown with pre-inoculated seeds. The calculated 'no reduction' level and '10% reduction' ECw level for salinity tolerance in non-inoculated soybeans would accordingly be 1.3 dS/m and 1.5 dS/m, respectively.

[6]**Peanut:** Tolerance levels shown for peanuts are based on ANZECC & ARMCANZ (2000b) Table 9.2.10. Even though the plant may tolerate higher salinity, it is proposed that pod growth may be affected at lower concentrations (source reference unknown). Allowing for levels considered to affect pod growth, the calculated alternative 'no reduction' level and '10% reduction' ECw level would see values of 1.1 dS/m and 1.4 dS/m, respectively.

[7]**Rice:** Tolerance levels provided for rice are for very slow-draining soils only, and during the establishment and reproductive phases. Rice is most sensitive in the period between the 3-leaf growth stage and panicle initiation, expressed by reduction in the number of tillers and subsequent reduction in grain yield (Zeng et al., 2001).

[8]**Cowpeas:** The values are derived from the ANZECC & ARMCANZ (2000b) guidelines for 'no reduction' level and '10% reduction'. The ECw level would vary for seed cowpeas (1.1 dS/m 'no reduction', 1.8 dS/m '10% reduction', and 2.9 dS/m '25% reduction') and Caloona cowpeas (1.3 dS/m 'no reduction', 1.9 dS/m '10% reduction', and 2.8 dS/m '25% reduction'), respectively.

Table 4. Forage crops, pasture grasses and clovers — water salinity tolerance (ECw)

This table indicates the yield reductions that could be expected when various pasture and forage crops are irrigated with saline water and grown in moderate- to slow-draining soils.

Crop	No reduction (dS/m)	10% reduction (dS/m)	25% reduction (dS/m)
Forage crops			
Oats	3.3	3.6	4.1
Sudan grass	1.8	3.4	5.7
Corn (forage)	1.2	2.1	3.4
Grasses			
Puccinellia [1]	10.0	14.5	na
Tall wheat grass	5.0	6.5	8.9
Couch grass	4.6	5.6	7.1
Rhodes grass	4.6	6.7	9.8
Buffel grass (Nunbank)	4.0	4.9	6.4
Perennial ryegrass [2]	3.7	4.6	5.9
Buffel grass (Gayndah)	3.6	4.3	5.2
Phalaris	2.8	na	na
Fescue	2.6	3.8	5.7
Crested wheat grass	2.3	4.0	6.4
Kikuyu	2.0	4.2	7.5
Green panic	2.0	2.9	4.4
Setaria (Nandi)	1.6	2.1	2.9
Pangola grass	1.3	3.0	5.4
Lovegrass	1.3	2.1	3.3
Paspalum	1.2	1.9	3.0
Cocksfoot	1.0	2.1	3.7
Legumes			
Vetch [4]	2.0	2.6	3.5
Barrel medic (Cyprus)	2.0	2.4	3.1
Balansa clover [1]	2.0	na	na
Persian clover (Shaftal) [1]	2.0	na	na
Stylo (Townsville)	1.6	1.9	2.4
Lucerne (USA)	1.3	2.2	3.6
Strawberry clover (Palestine)	1.1	1.7	2.7
Berseem clover (USA)	1.0	2.1	3.8
Red clover	1.0	1.5	2.4
Snail medic	1.0	1.5	2.3
Subterranean clover [3]	1.0	1.1	2.4
White clover (New Zealand)	0.7	1.3	2.4
Rose clover (Kondinin)	0.7	1.4	2.5
Barrel medic (Jemalong)	0.7	1.5	2.8

[1]There is no reference to salinity tolerance for these crops, forages and pasture types in the ANZECC & ARMCANZ (2000b) guidelines. The values presented are from an unreferenced source and should be considered with caution.

[(2)(3)]There is no reference to salinity tolerance for perennial ryegrass or subterranean clover in the ANZECC & ARMCANZ (2000b) guidelines. The values presented are consistent with Table 7 of the crop tolerance tables from WA Department of Agriculture & Food (Neil Lantzke, Tim Calder and John Burt).

NOTE: Salinity tolerance values provided by WA DA&F are for loam soils [leaching fraction presumed to be ANZECC & ARMCANZ (2000b; equation 4.1) value for loamy soil of 0.33], rather than values for a moderate-to-slow draining soil generally provided in this table (leaching fraction factor of 0.3). The results for perennial ryegrass[(2)] are consistent with Brown and Bernstein (1953) presented in FAO (1999) and Maas (1984).

[(4)]The values presented for vetch[(4)] are consistent with Ravikovitch and Porath (1967) presented in FAO (1999), and Maas (1984).

For further information contact your Local Land Services office.

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[i] Salt tolerance is not a simple, fixed characteristic of plants. The effect of applying saline irrigation water on the salinity of soil in the plant root zone is subject to a range of soil chemical, soil physical (texture and drainage), agronomic and climatic conditions (rainfall and evapotranspiration) interacting with the growing plants. The information in this Primefact is provided as a guide to identify potential water quality concerns. It is a simplified treatment of a complex interaction of multiple factors. The salinity tolerance tables provide

a rough estimation of the plant growth and yield effect of the soil salinity in the root zone (measured in a saturated soil extract and given the term ECse), potentially resulting from the saline irrigation water (ECw) being applied to a particular soil texture. Other factors such as initial (or starting) soil salinity, crop stresses and growth stage are unable to be incorporated in these estimations, but could be important in some situations.

To relate ECw to ECse for a moderate- to slow-draining soil, equation 4.1 (Paper 4, Volume 1, Chapter 4; ANZECC & ARMCANZ, 2000a) has been applied using the yield threshold data ('no yield reduction', '10% yield reduction', and '25% yield reduction') for different crop types provided in Table 9.2.10 (Paper 4, Volume 3, Chapter 9; ANZECC & ARMCANZ, 2000b) and a leaching fraction of 0.3, in most instances. 'No reduction' means a less than 10% yield reduction.

Note: Some of the research cited in the ANZECC 2000 tables (ANZECC & ARMCANZ, 2000a; and 2000b) applying saline solutions to established plants, was intended to develop **relative** salinity tolerance between plant types, and does not necessarily indicate actual threshold levels (Daniells et al., 2001). Soil testing to establish the existing conditions is a key requirement for evaluating the risk of applying saline irrigation water.

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