WATER-LOGGING OF COTTON

In Australia, most of the cotton is grown using furrow irrigation on heavy clay soils. Because these soils drain slowly, waterlogging can significantly limit irrigated cotton production. Hence, many cotton crops are subjected to some degree of waterlogging. This problem is accentuated by rainfall after irrigation and inadequate land preparation.

Symptoms of waterlogged cotton include a general yellowing of the crop and stunted growth.

Good water management and improved drainage can minimise yield reductions from waterlogging and increase profitability. Waterlogging may reduce crop yield by up to 1 bale/ha. Crop yields may be affected even before symptoms are noticed.

CAUSES OF CROP DAMAGE UNDER WATERLOGGING

Waterlogging can severely restrict crop growth and may kill plants in extreme cases. This is because oxygen (O_2) diffuses 10,000 times more slowly in water than in air. Hence, soil O_2 supply from atmosphere is reduced while other toxic gases (eg CO_2 and ethylene) generated by plant roots and microorganisms accumulate to high and possibly lethal concentrations in the soil.

The major and immediate effect of waterlogging is blocking transfer of O_2 between the roots and the soil atmosphere. Plant roots may become so O_2 deficient that they cannot respire. As a consequence, root growth and absorption of nutrients is decreased. Availability of nutrients in the soil is also reduced.

Waterlogging is often compounded by soil compaction. However, reduced tillage and permanent bed systems may alleviate soil compaction and the severity of waterlogging. Cloudy weather associated with wet seasons may enhance the waterlogging effect as well as the incidence of some cotton diseases. Low rates of evaporation and reduced radiation (sunshine) may encourage waterlogging and reduction in yield.

NUTRIENT AVAILABILITY DURING WATERLOGGING

The decline in soil O_2 concentration effects the oxidation stage of many nutrients. Once molecular oxygen (O_2) is removed from the soil, a sequence of chemical reduction takes place as the intensity of waterlogging conditions increases (Table 12-1). The time to reach each stage in Table 1 will vary considerably, depending on soil type (texture), compaction, soil organic matter, pH and chemical composition. This can range from hours to days. The intensity of each waterlogging event will also vary from one event to the next.

The availability of N, Mn and Fe are directly affected by waterlogging. Zinc availability is reduced due to the formation of insoluble $Zn(OH)_2$ and $ZnCO_3$. In alkaline and/or calcareous soils, the availabilities of Fe and Zn tend to be low, due to adsorption onto clay surfaces or $CaCO_3$. A high concentration of bicarbonate may inhibit Fe and Zn uptake and translocation.

Soil management that promotes good surface and sub-surface drainage will delay the onset of these chemical reduction processes, thereby reducing the severity of waterlogging (see the SOILpak manual).

NUTRIENT UPTAKE DURING WATERLOGGING

The lack of oxygen encountered in waterlogged soil impairs water and nutrient uptake. Nitrogen, potassium and iron uptakes are particularly affected in cotton subjected to waterlogging.

NITROGEN

Besides impairment of root uptake activity, an added penalty under waterlogging is the denitrification of soil mineral nitrogen. Therefore, even after waterlogging has ceased, there may be less nitrogen available for the crop. In this circumstance, much of the yield lost through temporary waterlogging can be recovered by supplying N directly to the

Table 12-1. ***Sequence of chemical reduction of nutrients as waterlogging intensifies.***

Chemical reaction	Increasing waterlogging intensity
Onset of NO_3^- reduction to nitrite	↓
Onset of Mn^{2+} formation	↓
Free oxygen (O_2) depleted; normal root respiration slows	↓
Nitrate (NO_3^-) completely reduced	↓
Onset of Fe^{2+} formation (but plants cannot absorb due to low root activity)	↓
Onset of SO_4^- reduction (H_2S formed)	↓
Absence of SO_4^-	↓
CO_2 reduced to methane (CH_4)	↓

leaves as a foliar spray. Yield reduction from waterlogging may be severe but applying foliar fertilizer (about 8 kg N/ha before each of the first three irrigations) can prevent part of that yield loss (Table 12-2).

Foliar N is more effective in increasing the yields of waterlogged cotton when applied one day before irrigation under hot, sunny conditions. Foliar N is less effective when applied during cool, overcast conditions, or when high concentrations of soil N are available to the crop before waterlogging. Therefore, foliar N applications may be beneficial on fields with little slope and where sub-optimum amounts of N fertilizer have been applied. Plant tissue testing may be used as a guide to indicate susceptibility to waterlogging and response to foliar N.

POTASSIUM

Waterlogging is possibly involved in premature senescence of cotton. Under waterlogged conditions, uptake of K by the cotton crop may be reduced, predisposing the crop to the premature senescence syndrome (see section on 'Premature senescence' in this manual).

IRON

The young leaves of iron deficient plants become yellow between the veins (chlorosis). The veins usually remain green, unless the deficiency is severe. The whole leaf may eventually turn white. Although the plant may contain high concentrations of iron, most of it is unavailable for chlorophyll production and the leaves lose their green colour.

When a soil is waterlogged, the passage of carbon dioxide out of the soil is blocked. The CO_2 concentration builds up in the soil solution forming bicarbonate ions. This increases soil pH, which in turn increases the concentration of bicarbonate and alkalinity in the leaf tissues. Under these conditions, iron becomes unavailable (ie the active iron (Fe^{2+}) is converted to the inactive forms (Fe^{3+} and others) and symptoms of chlorosis appear. The soil syndrome is referred to as lime-induced chlorosis.

Waterlogging can also induce iron chlorosis particularly where soil phosphorus is high. Phosphate reacts with soluble iron to form insoluble iron phosphates. The imbalance between iron and phosphorus in the leaf tissue is observed as very yellow leaves about two nodes from the terminal.

Diagnosing iron chlorosis is complicated because the total iron content of the leaf is not closely related to the physiologically active iron (Fe^{2+}) component of total iron content. To determine the Fe^{2+} content, fresh leaves must be analysed within a few hours of sampling; commercial laboratories cannot do this. The total Fe content of yellow leaves is often similar or higher than that of green leaves, which may incorreclty indicate that iron is not deficient.

Foliar application of 200 g Fe/ha with a ferrous sulphate may return foliage to its normal colour within 2-3 days.

MANAGEMENT OPTIONS TO MINIMISE WATERLOGGING DAMAGE

- field design. A uniform slope of at least 1:1500 is best for draining irrigation water or rainfall from a field. Tail drains should be designed to remove run-off as quickly as possible.
- high beds assist drainage and decrease waterlogging in irrigated fields.
- fast irrigation times decrease waterlogging. Use more or larger diameter siphons, greater pressure head or shorter rows. The aim should be to have water on/off each furrow in four hours.
- foliar N fertilizer. Apply 8kg N/ha where waterlogging is likely. Higher rates of N can burn foliage. Application of the foliar N on a field already waterlogged will not necessarily alleviate existing damage.
- under some circumstances, foliar iron application of 200g Fe/ha (*eg* 1 kg $FeSO_4$/ha) may prevent iron chlorosis and may increase yield. Chelated iron may be applied to the soil pre-sowing.

Table 12-2. Foliar N may reduce yield loss in waterlogged cotton.

	No foliar N	Foliar N applied
Not waterlogged	8.51 b/ha	8.30 b/ha
Waterlogged	8.01 b/ha	8.33 b/ha