3.4 Impact of waterlogging on cotton

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Key points

- Waterlogged soils reduce the access of the roots to oxygen, impairing root growth and function and ultimately nutrient uptake. Toxic gases in the waterlogged soil can also increase.
- Waterlogging reduces cotton yields by causing fruit shedding and slowing growth of new fruiting sites which reduces the number of bolls on the plant.
- Waterlogging can be avoided by optimising field design, bed formation, and irrigation scheduling. The application of some foliar fertilisers may also assist in fields known to waterlog.

Cotton is known to be poorly adapted to waterlogged conditions. In Australia, cotton production is concentrated on soils with inherently low drainage rates, which, combined with the almost exclusive use of furrow irrigation and a summer dominant rainfall pattern, results in a significant risk of intermittent waterlogging.

Causes of waterlogging

When a soil is waterlogged the access of the roots to oxygen is impaired, reducing their ability to respire thus reducing root growth and function and ultimately nutrient uptake. There is also a build-up of toxic gases such as carbon dioxide and ethylene that are generated by the roots and micro-organisms which can impair root and whole plant function.

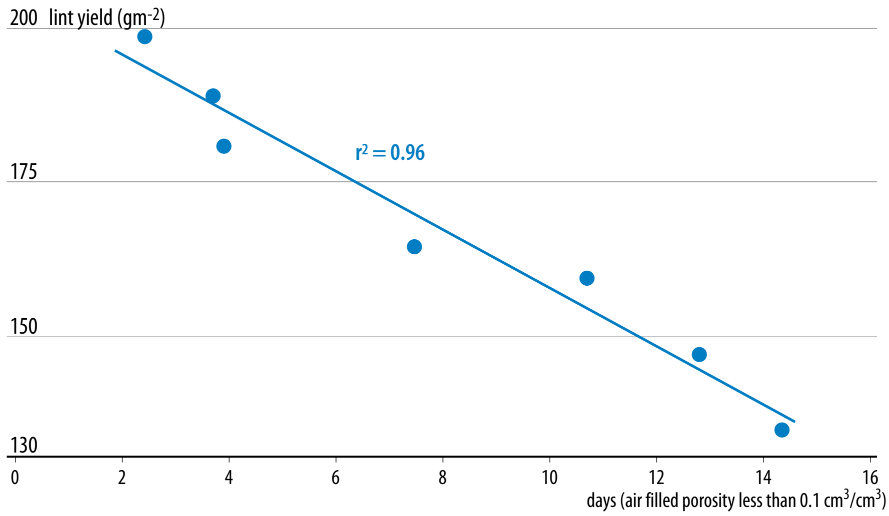
The waterlogging problem can be exacerbated through additional factors such as:

- soil compaction. There is less space for air to be present in the soil and transfer of air is impeded.
- excessive field length. This can lead to prolonged water application times, which in turn can cause waterlogging, especially at the head ditch end of the field.
- inadequate slope or poor levelling. Low slopes or areas within a field may not allow excessive water to move freely away from a growing crop.
- poor bed formation. Well-formed beds allow cotton roots to grow in soil that is freely drained.
- poor irrigation scheduling. Too frequent irrigations may predispose the crop to waterlogging.
- substantial rainfall after an irrigation event. This could expose the crop to longer periods of inundation.
- long periods of cloudy weather. Low rates of evaporation and reduced radiation (sunshine) may prolong waterlogging.

Impacts of waterlogging on crop yield and quality

Investigations in the early 1980's by the late Arthur Hodgson in Narrabri into the effects of waterlogging, showed that yield of field-grown cotton declined with duration of inundation at each irrigation event. To generate the effects of duration of inundation Hodgson varied the period of irrigation of the crop between 4 and 32 h. However, the degree of yield depression differed between his experiments. When the data of the experiments were combined, yield was strongly related to the number of days when air filled porosity of the soil (proportion of air present in the soil) at a depth of 10 to 20 cm was below 0.1 (i.e. 0.1 cm^3 of air/cm^3 of soil, or 10% air by volume). Lint yield was reduced by 48 kg/ha (0.2 b/ha) for every day of when the soil was low in oxygen (Figure 3.4.1). Hodgson found that there were no further reductions in yield after 96 h (4 days) of inundation across the growing season.

Figure 3.4.1. The relationship between yield and duration of inundation by irrigation from Hodgson (1982)



In field studies starting in the late 90s, also conducted at Narrabri, Bange, Milroy and Thongbai found some contrasting results to those of Hodgson. In some instances where certain agronomic practices were employed, no effects on yield or fibre quality were seen even when the crop had been inundated continuously for up to 72 h (3 d). Field experiments were conducted in which cotton crops were subjected to intermittent waterlogging by extending the duration of irrigations. Investigations compared the timing of waterlogging events, cultivar and landforming (hill height). To generate marked effects of waterlogging on yield it was necessary to reduce hill height. (Hodgson reported reductions in yields with the duration of 32 hours without the need to modify hill height.)

The recent results also showed that waterlogging early in crop growth had far greater influence on yield than waterlogging at mid-flowering or later. The effects of these treatments are summarised in Table 3.4.1.

Table 3.4.1. Different agronomic effects on yield and yield components after waterlogging (up to 72 h inundation)

Agronomic treatment	Maturity	Yield	Final boll number	Final boll size	Fibre length	Micronaire
Hill height (5 cm versus 15 cm)	✗	✓	✓	✗	✗	✗
Variety (Sicala V-2i versus Nucotn 37)	✗	✗	✗	✗	✗	✗
Early waterlogging Pre flowering	✗	✓	✓	✗	✗	✗
Late waterlogging Mid flowering	✗	✗	✗	✗	✗	✗

Source: 1990s studies by Bange, Milroy and Thongbai

The differences in severity of the impact of waterlogging between the two studies could be due to a number of reasons. It is feasible that oxygen levels were not as severely affected by inundation in the more recent experiments because since the 1980s there has been increased awareness within the Australian cotton industry of management practices aimed to maintain good soil structure. As a result, compaction is less severe and less widespread. In addition, there has been considerable improvement of water flow in furrow-irrigated fields through the use of laser-guided levelling systems. Indirect selection of cultivars more suited to the intermittent waterlogging experienced in the Australian growing environments may also have played a role.

Causes of yield reduction due to waterlogging

Waterlogging of cotton has been reported to cause reductions in root growth and nutrient uptake, leaf area and photosynthesis, all leading to restrictions in overall cotton growth and fruiting development.

Results of detailed measurements of crop growth in both the studies of waterlogging mentioned above show that when yield was reduced due to waterlogging it was associated with final boll number being reduced (Figure 3.4.2). Boll size and percentage lint were not affected. Reductions in boll number are commensurate with reductions in growth due to lower radiation use efficiency (amount of dry matter produced per unit of intercepted light), which impacts on the amount of assimilates available for plant growth. Results from these studies also suggested that this reduction in boll number is most likely associated with reduction in fruiting site production rather than increased shedding alone.

The suppression of radiation use efficiency is consistent with the reduction in photosynthesis and the reduced function of photosynthetic enzymes by waterlogging. Reduced concentrations of nitrogen (N) in a leaf can reduce leaf photosynthesis, and the amount of N in leaves is affected by N uptake. Work undertaken by Hodgson and MacLeod (1988) showed that, while leaf N of cotton was reduced due to waterlogging, applying foliar N in the days prior to waterlogging did not fully alleviate the reductions in growth in all cases nor did it rectify the leaf yellowing that occurred. This suggests that other mechanisms, in addition to those acting through the reduced uptake of N, were likely to be acting on leaf performance. The exact reasons for the reduction in photosynthesis and radiation use efficiency with waterlogged cotton are still to be clarified.

In addition to the physiological impacts of waterlogging on the crop there are also significant impacts on nutrient availability and uptake. The availability of N (Figure 3.4.3.), Fe and Zn (reduced) and Mn (increased) are directly affected by the decline in soil oxygen, and uptake of N, K and Fe by the roots is also impaired.

Figure 3.4.2. Results of studies by Bange, Milroy and Thongbai showing the relationship of yield and final boll number influenced by different waterlogging treatments.

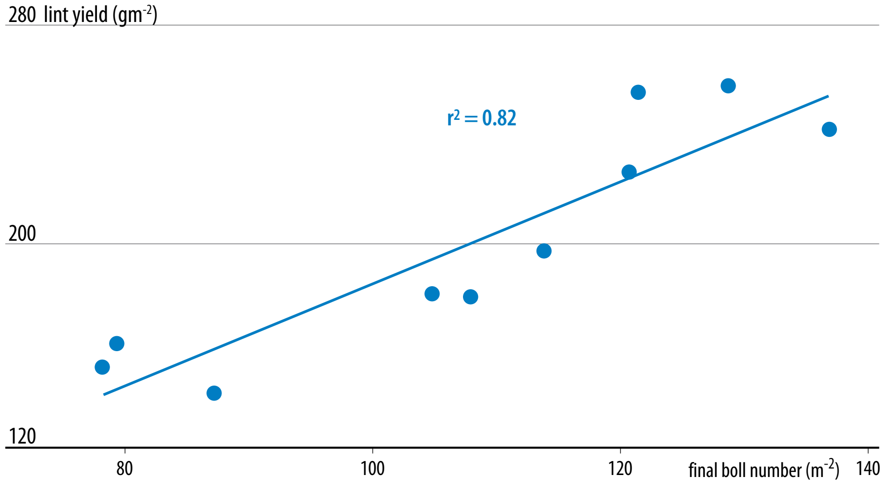
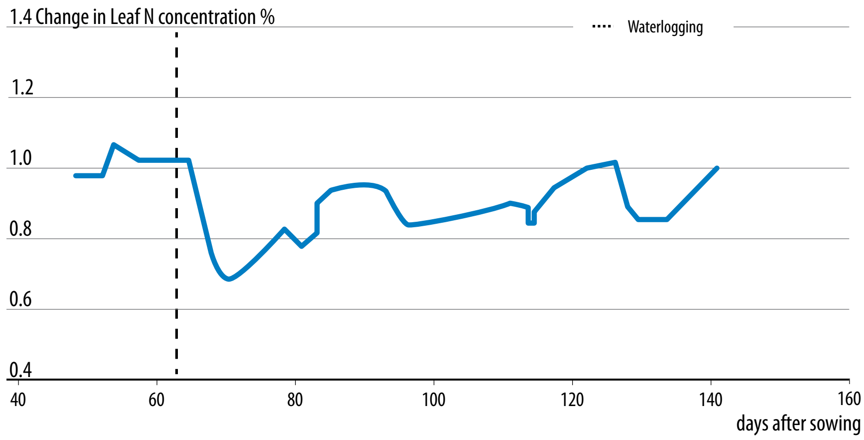
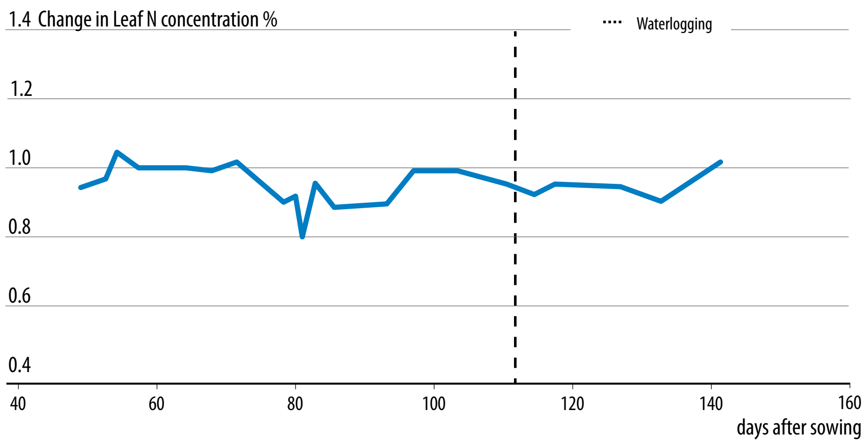


Figure 3.4.3. The impact of waterlogging on the N concentration of the most fully expanded leaf at the top of the plant. The graphs show the change from the non-waterlogged treatment. The heavy dashed line is the waterlogging event and the other lines are normal irrigation events.





Note the large impact caused by the early waterlogging event. (adapted from Milroy, Bange and Thongbai (2009)).

Management options to reduce waterlogging risk

Field design. A uniform slope of at least 1:1500 is best for draining irrigation water or rainfall from a field. Tail drains should also be designed to remove run-off as quickly as possible.

Hill height. Well-formed high beds will decrease waterlogging in an irrigated field.

Irrigation period. Keeping the period of single irrigation events to a minimum will minimise the risk of waterlogging. This can be achieved by assessing irrigation performance and optimising flow rates and irrigation run length to minimise inundation time (see WATERpak Chapter 5.3).

Increasing the water supply capacity may be required where siphon flow rates are increased to get the water on and off the field quickly. In addition, higher system capacity reduces the time it takes to irrigate the whole farm, giving farmers more flexibility to react to climatic influences such as a heat wave or waiting for a forecasted rainfall event.

Foliar fertiliser. Apply 8 kg N/ha just prior to a waterlogging event. Be careful not to use too high rates because foliage may burn. Applications on an already waterlogged field may have little impact. In some circumstances applications of foliar iron (Fe) may prevent leaf yellowing. See NUTRIpak for further details.

Irrigation scheduling. Ensure proper irrigation scheduling. Too frequent irrigations increase the risk of waterlogging. The use of soil moisture monitoring equipment can assist with optimising irrigation scheduling to reduce waterlogging risks and improve yields (see WATERpak Chapter 2.1).

Monitor growth. In some instances waterlogging may induce shedding and if conditions significantly improve and there is adequate nutrition, excessive vegetative growth maybe an issue. Only consider Mepiquat Chloride (Pix) when crops are recovered fully, as the use of this growth regulator may add additional stress, or have no effect.

Monitor weather. If feasible, monitor weather and delay irrigation if there is a high chance of significant rainfall to occur at the time of the scheduled irrigation.

Management of crops following flooding events

The impact of a flood event can range from complete crop failure to reductions in growth and yield. The effect depends on the severity (depth, water quality, flow) and length of inundation. Cloudy weather (low light), coupled with waterlogged soils also causes further impacts on crops. Under these conditions, cotton plants are likely to cease growth (e.g. production of new nodes) and then, as assimilate in the plant becomes limited, shed squares and fruit.

The way the crop is managed for crop recovery may change depending on the timing of these extreme events during the season. If a significant amount of the season remains, then the primary aim should focus on nursing the surviving crop back to a point where it can support new growth. If the flood events have occurred late in the season the focus should be on supporting fruit retention. A crop manager needs to ascertain if there is remaining season length to allow new fruit to be set, develop, and mature before the onset of cold weather.

The time for a new square to produce a flower is on average 23 days while it takes 63 days for a boll on average to develop into a harvestable boll. As the season progresses these times (for nodes, squares and flowers to develop) increase as temperature and light decrease. While new squares can be produced, the risk of these not contributing to final yield is considerable, especially late in the season. In some cases, crops may have reached the point of (or are rapidly approaching) the last effective square that results in the last effective flower. Growers and consultants can determine squares and fruit that are likely to mature using the "Last Effective Flower Tool" in CottASSIST.

For crops to again access to soil water and nutrition, surface roots will need to once again come into contact with oxygen once fields dry out. After this has occurred, the use of leaf testing may provide some guidance as to the plants nutritional requirements. Foliar applications of nitrogen, phosphorus, iron, zinc, and boron may alleviate immediate deficiency symptoms and help nurse plants along. Irrigation schedules may also need to be shortened to avoid stress as overall root function may have been impaired.

Chapter 3 of NutriPAK contains specific information relating to the application of nitrogen and foliar fertilisers, although information concerning nutrient requirements for late season flood affected crops is limited.

Avoid over-fertilising late season flood affected crops as this may induce unnecessary regrowth making defoliation more difficult, delay overall maturity and picking, affect quality, and could lead to pest and disease issues later in the season. Recovering crops can also have delayed maturity and may also inherit pest problems from nearby fields that mature earlier. Be vigilant in sampling recovering crops so that emerging pest issues especially secondary pests such as aphids, mites and silver leaf whitefly are detected early and can be monitored and managed if required.

Further Reading

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