FINAL REPORT 1.02.18

Four major questions were answered during the conduct of this research.

They are:

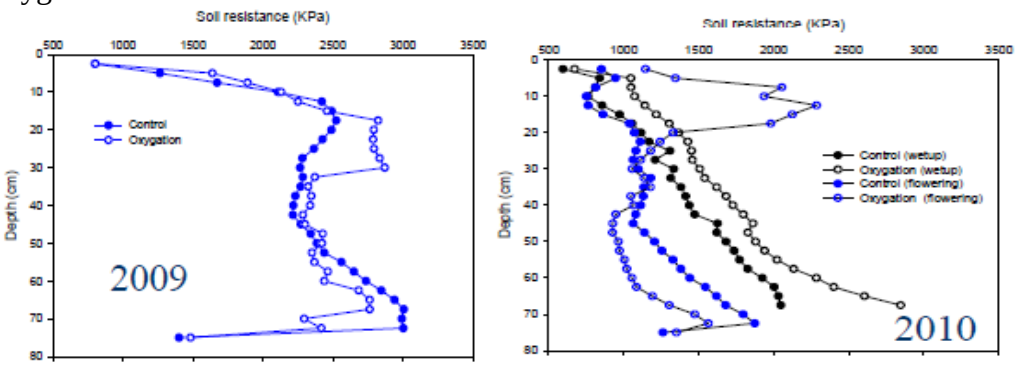
1. Under what conditions will there be a measurable positive effect of aeration?

a) Cropping cycle: We endeavoured to determine the long-term benefits [and draw-backs] of oxygation delivered through sub-surface drip irrigation [SDI] for cotton grown in a large replicated field trial on a heavy clay soil [a vertisol] in central Queensland. Yields in all years benefitted from oxygation, although the difference was not statistically different in each year, and the overall benefit was 14.7%.

Lint yield (bales/ha) in vertisol over six seasons

Trt	04/05	05/06	07/08	8/09	09/10	10/11	Combined
Oxygation	9.32	9.33	8.84	6.90	9.11	9.04	8.756
Control	7.35	8.02	7.89	6.47	8.33	7.71	7.628
Pvalue	0.078	0.005	0.031	0.532	0.242	0.112	0.166
SED	0.941	0.30	0.249	ns	ns	1.191	0.670

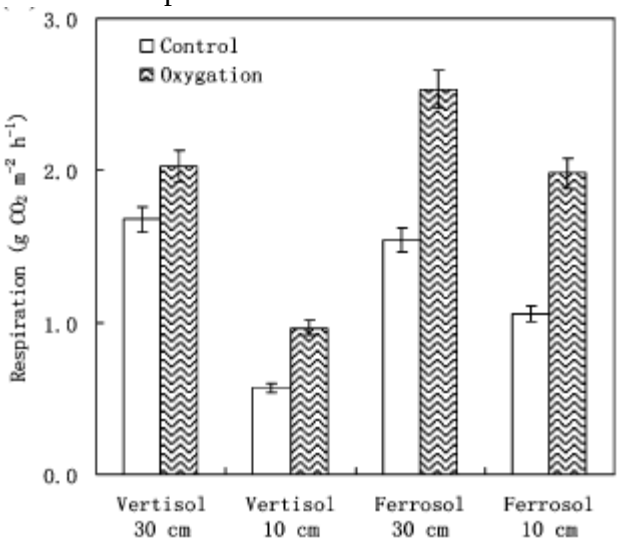
Extensive soil coring around emitters did show that root length density was greater with oxygation closer than more distant from the emitters. Light interception and leaf chlorophyll content close to boll filling were enhanced by oxygation. We did find effects of oxygation on soil penetrometer resistance, which was greater with oxygation due most likely to the more effective water uptake and drying of soil with oxygation.



b) Distance from venturi source of air: Field data from the same trial in 2005/6 suggest that there is no major difference in terms of benefit of oxygation allowing a drip line until beyond 165 m from the start of the drip line. Likwsie in 2008/9 and 2011/2 there was no differential effect of oxygation according to distance from the venturi, although in both the latter years there was an indication [non-significant] of a greater positive effect further from the venturi.

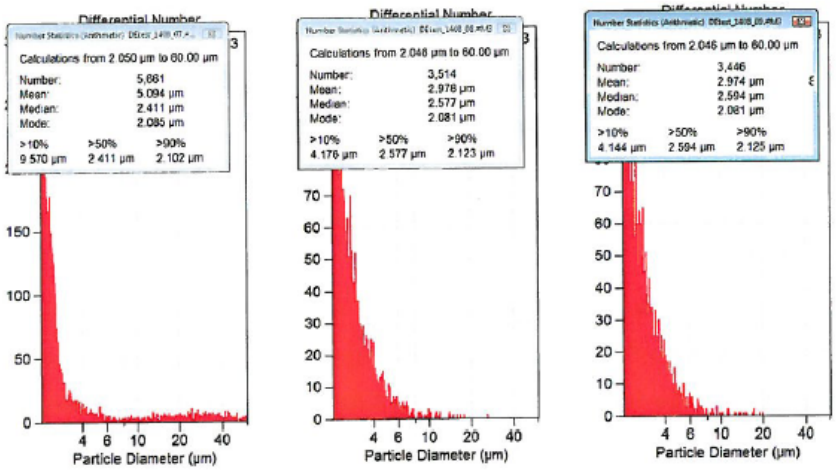
c) Soil type and emitter depth: Our data from some large container trials [LxBxH: 3.1 x 0.85 x 0.6 m^3] showed that cotton yield increased significantly at emitter depth (30 cm vs 10 cm) more so in a vertisol than a ferrosol, and the values of the fresh biomass and dry matter of cotton in oxygation treatments were somewhat greater (7–34%, 1–31%) compared with the control. Interaction effects between emitter depths and

oxygation were noted for fresh biomass and dry matter yield of cotton; oxygation was more effective at 10 than 30 cm emitter depth. The same was noted for measurement of soil respiration, the increase with oxygation being greater at 10 cm emitter depth than 30 cm depth for both ferrosol and vertisol.



2. Why should there be a measurable effect?

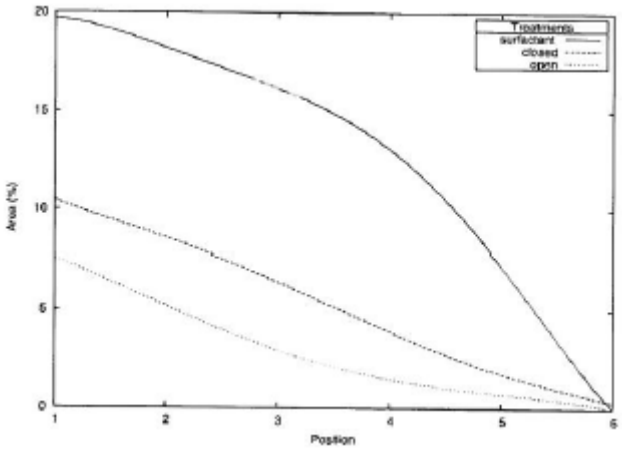
a) Size distribution of air bubbles in pipes: using a Beckman Multisizer we studied the size distribution of bubble generated with a Mazzei venturi. Bubbles of <20 microns disappeared soon after aeration, leaving those <20 microns in a suspended state. It is these latter that reach greater distance along drip tubes.



(a) (b) (c)

Measurement of bubbles sizes and distribution at higher aeration rate of 12% during oxygation (a) initially. (b) after five minutes of oxygation and (c) after ten minutes of oxygation using Beckman Coulter Counter Multisizer3.

b) Distance from venturi: we studied the effects of distance from the venturi on bubble size distribution, and found that often more air was released from emitters closer to the venturi than more distant. The following graph, developed from our bubble visualisation technology, shows the decline in percentage air (as bubbles) with distance from the venturi, distance 1=15.6 m, 2=36.5 m, 3=71.5 m, 4=96.6 m, 5=121.3 m, 6=176.8 m.



3. How to better deliver aeration to irrigation water to achieve the desired effects?

a) Surfactants: as seen in the graph above, the addition of surfactant [at 2 ppm BS1000^{TM}] prior to the venturi, enables achievement of higher aeration percentages along the irrigation drip tube.
b) Microbubbles and Seair: we compared Seair and Mazzei aerators [Seair has claims of bubbles of 5 microns – we were not able to verify this], and found no significant difference between the two, indeed, in that trial we did not measure significant effects of oxygation on anything other than leaf chlorophyll concentration. In part the effect of shallow emitters in this trial causing effervescence reduced the benefit of oxygation.
c) Other approaches: oxyfertigation is a recent invention where a sealed air or oxygen injector chamber is connected to a small-pore diffuser [such as a material used to make porous caps for tensiometers] near the outlet assembly of the drip irrigation system where dissolved oxygen concentration as high as 25.6 mg L^{-1} is deliverable. This has been sued to good effect in Spain.

4. What other possible benefits may be obtained with aeration?

a) A noted increase in crop WUE by 27% on average over all years with oxygation for the cotton field trial.
b) In parallel to research with cotton we have trialled a range of other crops, including pineapple, alfalfa, figs, apricots and grapes, with all showing some benefit to oxygation.
c) We are now in the process of requesting funding to look at the possible beneficial effects of oxygation in reducing the emissions of NOx, which occur in anoxic or hypoxic soils, especially with sugarcane.

Publications arising:

Journal articles

McHugh, A.D. Bhattarai, S.B. Lotz, G. and Midmore, D.J. (2008). Soil erosion and off-site movement of nutrients and pesticides from furrow and subsurface drip irrigated cotton on a vertisol. Agronomy for Sustainable Development 28: 507-519.

Bhattarai, S.P., Midmore, D.J. and Pendergast, L. (2009). Oxygation effect on growth, gas exchange, water relation and salt tolerance of vegetable soybean and cotton in a saline vertisol. Journal of Integrative Plant Biology 51 (7): 675-688.

Bhattarai, S.P., Midmore, D.J. and Su, N. (2010). Sustainable irrigation to balance supply of soil water, oxygen, nutrients and agro-chemicals. In: Biodiversity, Biofuels, Agroforestry and Conservation Agriculture. Sustainable Agriculture Reviews 5: 253-286.

Chen, X.M., Dhungel, J., Bhattarai, S.P., Torabi, M., Pendergast, L. and Midmore, D.J. (2011). Impact of oxygation on soil respiration, yield and water use efficiency of three crop species. Journal of Plant Ecology 4(4): 236-248. *doi:10.1093/jpe/rtq030*

Torabi M., Midmore D.J., Walsh K.B., Bhattarai S.P. and Tait L. (2102). Analysis of factors affecting the availability of air bubbles to subsurface drip irrigation emitters during oxygation. Irrigation Science [In Press].

Bhattarai, S.P., Wassink, D., Midmore, D.J., Balsys, R. and Torabi, M., (2012). The total air budget in oxygenated water flowing in drip tape. Journal of Water research. [Submitted].

Conferences

Midmore, D.J., Bhattarai, S.P. and Pendergast, L. (2007). Oxygation – can roots respond to additional oxygen? In: Root and Soil Biology in Agriculture: towards a better integration. CSIRO Plant Industry, Canberra, 31 January – 3 February, 2007. [Invited presentation]

Midmore, D.J., Bhattarai, S.P., Pendergast, L. and Torabi, M. (2007). Oxygation: aeration of subsurface drip irrigation water and its advantages for crop production. In: Australian National committee on Irrigation and Drainage conference - Sharing the water; food, fibre, people and environment. Bundaberg, 19-22 August.

Midmore, D.J., Bhattarai S.P., Pendergast, L., Dhungel, J., Torabi, M. and Chen, M. (2009). Oxygation – capitalising upon the benefits of aerating irrigation water for annual and perennial cropping. In: Irrigation and Drainage Conference 2009, Irrigation Australia Ltd, Swan Hill, Vic, Australia, 18 – 21 Oct.

Bhattarai, S. P., Midmore, D.J., Pendergast, L. and Ronnfeldt, A. (2011). Oxygation: using aerated water for cotton irrigation with sub-surface drip: Opportunities for gains in yield and water use efficiency. Irrigation Australia Conference, 22 - 25 August 2011, Launceston, Tasmania, Australia.

Other [magazines] articles

Bhattarai, S.B. and Midmore, D.J. (2008). Potential benefits of oxygation-aeration to the Australian fruit industry. Australian Fruitgrower 2(1): 22-23.

Bhattarai, S.P., Midmore, D.J. (2009). Potential benefits of oxygation-aeration of irrigation water. Australian Nutgrower Dec. 38-40.