Natural based systems in treating blueberry irrigation runoff: a best practice trial

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The Clean Coastal Catchments (CCC) research project has launched a new trial to assess the effectiveness of 'natural' strategies for removing nitrogen from crop irrigation runoff at the Wollongbar Primary Industries Institute in Northern NSW.

An artificial wetland (subsurface flow) and a woodchip bioreactor trial have been installed adjacent to the CCC Blueberry Nutrition Research Facility where 300 potted blueberry plants are being grown under differing fertigation regimes to understand their nutritional requirements. This wetland and bioreactor research will study how much nitrogen can be removed by these structures from irrigation runoff draining from the potted blueberry experiments.

Excess nitrogen from agricultural fertilisers (specifically nitrate, NO^3-N) poses a serious environmental threat to waterways, groundwater reserves and estuaries, increasing the risk of eutrophication, harmful algal blooms, low oxygen, proliferation of aquatic weeds and potentially increases the emission of greenhouse gases. In a possible solution to this problem, beneficial anaerobic bacteria living within wetlands and woodchip bioreactors can consume excess nitrate from irrigation runoff.

What is eutrophication?

Eutrophication is the process in which a water body becomes overly enriched with nutrients, leading to plentiful growth of simple plant life. The excessive growth (or bloom) of algae and plankton in a water body are indicators of this process. Eutrophication is considered to be a serious environmental concern since it often results in the deterioration of water quality and the depletion of dissolved oxygen in water bodies. Eutrophic waters can eventually become "dead zones" that are incapable of supporting life.

Source: byjus.com

The aim of this research is to estimate the ability of both a subsurface flow wetland and wood chip bioreactor at reducing the concentration of nitrogen from blueberry irrigation runoff water. Specific objectives of the study are to:

- Estimate the fate of Total Nitrogen (TN), Ammonia (NH^4-N) and Nitrate (NO^3-N) within the bioreactors and wetland;
- Determine the maturation time for peak removal within the bioreactors and wetland (i.e. how long does it take for these systems to begin to work);
- Calculate the nitrogen removal rate of the systems, such that nitrogen removal can be equated to grams of nitrogen removed per m^2 or m^3 of the specific treatment cell;

- Determine design and construction schematics for the bioreactor and wetlands that can be replicated by local farmers;
- Provide best practice specifications, along with estimated costs, for local berry farmers interested in installing their own bioreactor or constructed reed bed wetland.

Nitrogen fertiliser is applied to blueberry crops in the forms of ammonium and nitrate but being highly soluble, it is the nitrate that routinely leaches from agricultural soils and is a predominant form of nitrogen loss from farms.

In recent years there has been increased research into the treatment of agriculture ground water high in nitrate. This research has focused on the relatively simple heterotrophic microbial mediated denitrification reaction (Kadlec 2009), which converts water soluble nitrate to dinitrogen gas (N_2). This chemical process occurs under anaerobic conditions in the presence of a carbon supply (typically organic matter).

Bioreactors and constructed wetlands create the required conditions to instigate the rapid conversion of nitrates into dinitrogen, providing a viable method for reducing excess nitrogen in water flowing from intensive horticultural operations, including hydroponic fertigation systems.

Bioreactor size and treatment performance

There is currently only limited information available to industry regarding guidelines for the appropriate sizing of denitrification bioreactors. This is most likely due to their relative infancy as a technology and limited field scale implementation.

A number of researchers (Robertson 2010; White et al. 2021) report high nitrate removal from denitrifying bioreactors, with reported nitrate reduction percentages routinely greater than 80% for high nitrate waters from a range of intensive land uses.

A range of removal rates have been reported, from 6.5g of nitrogen per cubic metre of media per day through to 16.15g nitrogen per cubic metre of media per day (Robertson 2010; White et al. 2021), and denitrification is maintained even when the concentration of nitrogen in the drainage water increases. This suggests that the concentration of nitrate may not be a rate-limiting factor in the overall nitrate loss within denitrifying bioreactors (Robertson 2010), with hydraulic flow (i.e. the time spent within the bioreactor), the physicochemical parameters of the bioreactor (temperature, pH, oxygen concentration) and the design of the bioreactor itself being other key factors controlling performance.

Experimental Design

Figure 1 shows the proposed sampling schematic. Irrigation runoff water will be collected in a common collection sump, prior to being dosed to either the bioreactor trial or the wetland trial. The sizing of the trial bioreactors and wetland are vital to the success of this experiment. As such, they have been carefully designed to ensure that the nitrate removal within the system occurs at a measurable rate, such that nitrate reduction rates can be calculated. The design of the structures can be scaled up for varying inflow volumes and nitrogen concentrations.

All water samples to be analysed for:

- Total Nitrogen,
- Ammonia,
- Nitrate and Nitrite,
- Organic Nitrogen,
- Biological Oxygen Demand
- Total and Dissolved Carbon, plus
- Insitu measurements of pH, Redox Potential, Temperature, EC

Water Sampling

Bioreactors have the capacity to begin removing nitrates from irrigation inflow water within just a few weeks of installation, allowing for water sampling for the bioreactor trials to commence as of February-March 2023. Sampling from the wetland is not scheduled to commence until spring 2023 after the newly planted wetland has had time to establish and grow.

The CCC research team will assess seasonal variations in the effectiveness of the bioreactor trial during the relatively dry winter period on the north coast of NSW, as well as both wet and dry periods in summer. Likewise, the wetland trial will be conducted during both summer wet/dry periods and throughout winter, traditionally the drier condition of the subtropical climate.

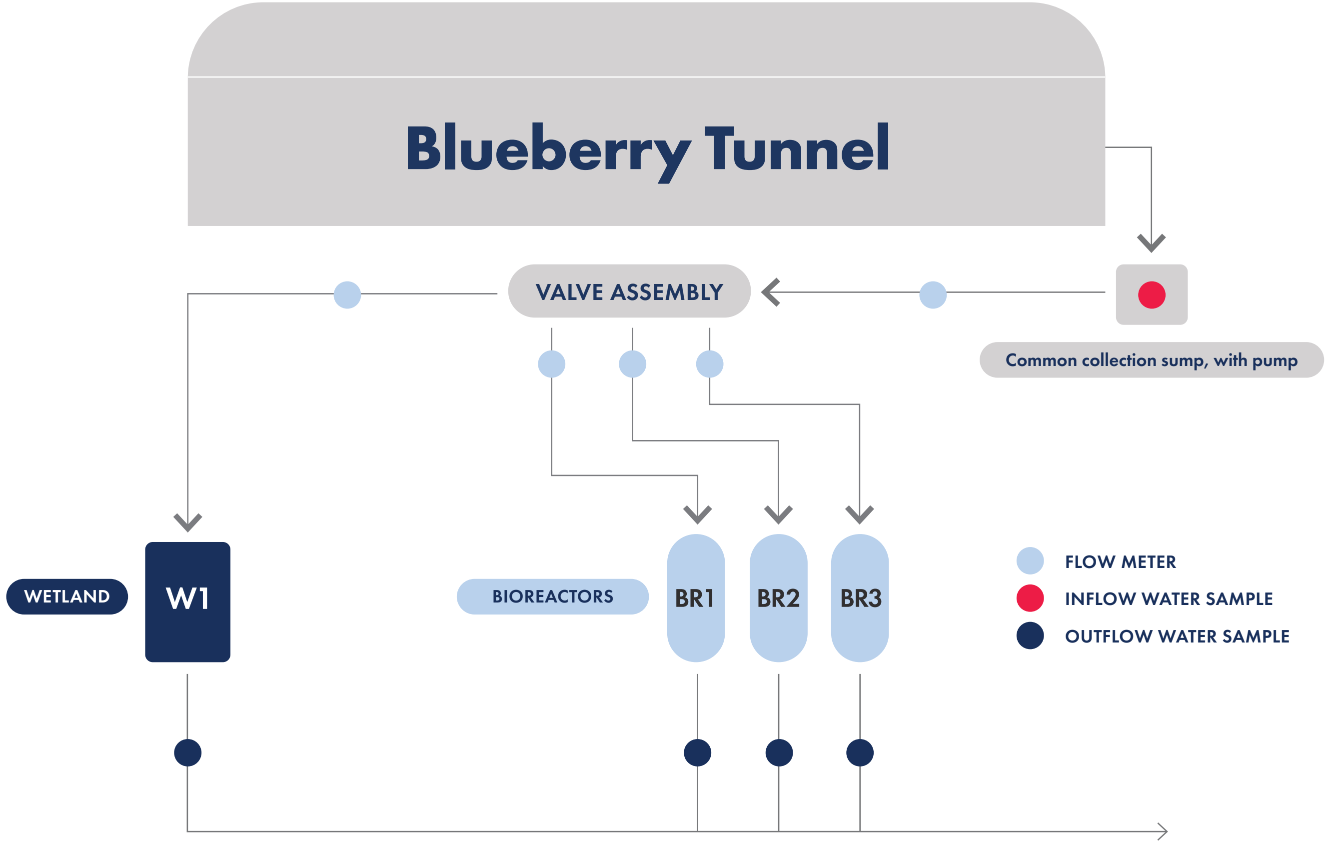
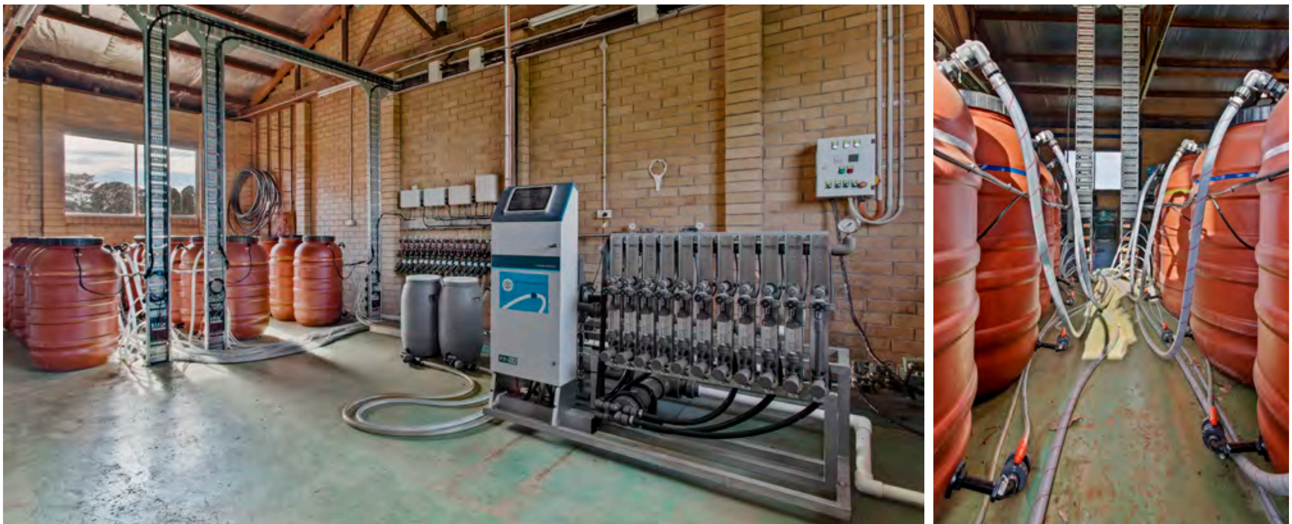


Figure 1. Design schematic. Source: Mark Bayley Consulting

Installing pipes to drain waste water from 300 potted blueberries, into a sump tank that will feed the bioreactor and wetland structures, at the Wollongbar Primary Industries Institute. Photo credit: Diana Unsworth

Bioreactor drums filled with wood chips. Photo credit: Diana Unsworth

Artificial wetland reedbed under construction at Wollongbar. Photo credit: Diana Unsworth



Fertigation barrels in the control room at Wollongbar. Photo credit: NSW DPI

Conclusion

This goal of this CCC research is to estimate the nitrogen reduction performance of bioreactors and constructed wetlands at various inflow volumes and nitrogen concentrations. These findings will then underpin the development of best practice specifications, along with estimated construction and maintenance costs, and will be published as guidelines for intensive agriculturalists to determine and cost the right method and design of denitrification options specific to their situation.

For more information

Visit: www.dpi.nsw.gov.au/agriculture/water/clean-coastal-catchments

Visit: www.marine.nsw.gov.au/marine-estate-programs/marine-estate-management-strategy

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