NITROGEN MANAGEMENT BY WATERCRESS (*NASTURTIUM OFFICINALE*) IN HYDROPONIC CONDITIONS

Charlotte Robertson[a,b], Brent Clothier[a], Siva Sivakumaran[a], Andrew McLachlan[a], Ian McIvor[a], Heather Meikle[b]

[a] *Sustainable Production, The New Zealand Institute for Plant & Food Research Limited, Tennent Drive, Palmerston North, 4474*
[b] *Science Department, Palmerston North Girls' High School, 238 Fitzherbert Avenue, Hokowhitu, 4410*

Abstract
Nitrate uptake by hydroponically grown watercress (*Nasturtium officinale*) was quantified over a 10 week period to determine whether watercress could be used to manage nitrogen pollution in waterways.

Germinated watercress was grown hydroponically in a glasshouse using a sterile Grodan® (rockwool) medium. A constant nutrient concentration and pH were maintained throughout the experiment. This involved regular (daily) determination of nutrient conductivity factor in the solution and addition of nutrients to compensate for plant uptake. Nitrate-nitrogen levels in the hydroponic solution were monitored weekly using an RFA-300 (Rapid Flow Analyser). Each week, 10 plants were randomly selected and destructively sampled for dry matter and total nitrogen (TN) determination. Plant nitrogen levels were quantified using a LECO Truspec C/N analyser.

The distribution of TN throughout the plant was not uniform. TN content was highest in the leaves and least in the roots. Plant dry matter and TN content both increased in a similar, exponential-like manner between Days 28 and 56. Rate of increase of both plant mass and N uptake slowed after Day 56, although TN mass continued to increase as plant biomass increased. That is, if the plant was actively growing, it took up N. Leaf TN concentration peaked at 6–7% at Day 21, and slowly decreased to just over 4% on Day 70.

To maximise TN removal, watercress should be harvested when the rate of nitrate uptake is at its maximum. In this experiment, this was at Day 32. This study needs repeating in field conditions in polluted waterways.

Introduction
Pollution, particularly by phosphates and nitrogenous compounds, is a key cause of excessive algal growth, loss of native aquatic flora and fauna, and deterioration of waterways. As a result, scientists and world leaders are increasingly concerned that there may not be enough clean water in the world to support humans in the future. Therefore society needs to learn to look after waterways better than has been practiced before, and to clean up what needs to be cleaned up. We therefore need to continually improve how we look after our waterways, and clean up polluted waterways where we can (Smith, 1999; Sorrell, 2010).

The status of a freshwater ecosystem is often closely linked to human activity – industry, agriculture and human settlements are usually concentrated alongside waterways. The leading issues for waterway nutrient and sediment pollution are agriculture; town/city sewerage and industrial discharges; and river engineering (Chadwick, 2010).

Waterways in New Zealand are also becoming increasingly polluted. For example, the Manawatu River has recently been classed as 'unhealthy' and 'heavily polluted' by world standards (Young, 2009). Results of tests on the Manawatu River's rates of Gross Primary Productivity (GPP) are among the highest internationally. In a 2009 report, Roger Young stated that "…sites with high rates of GPP are likely to experience algal blooms" (Young, 2009). Toxic algal blooms are reported with increasing frequency in reaches of the Manawatu River and its tributaries (e.g. Mangatinoka River) (Young, 2009; Morgan & Burns, 2009). Many New Zealand waterways are polluted by excess nitrogen from farm runoff and human activities. Watercress (*Nasturtium officinale*), an edible aquatic herb belonging to the Brassicaceae (cabbage) family, is a 'luxury feeder' that can grow rapidly and take up nitrogen in excess of its growth requirements Chapin (1980) and NIWA (2008). It could be an ideal plant to remove nitrogen from waterways (Vincent & Downes 1980). In this project we quantified how much nitrate the watercress plants could take up from hydroponic solution over 10 weeks, in order to determine whether watercress could be used to manage nitrogen pollution in waterways.

Methods

The trial was carried out in hydroponic runnels in the same glasshouse. A total of 200 plants were used; each plant was allocated a number 1 to 200. A random number generator was used to randomly select plants for analysis for the duration of the experiment.

Germinated watercress was grown in a glasshouse hydroponically (Figures 1A and 1B) in a sterile Grodan® (rockwool) medium. The composition of the hydroponic nutrient solution is shown in Table 1.

A constant nutrient concentration and pH were maintained in the hydroponic solution throughout the experiment. This was achieved by regular (daily) monitoring using a Bluelab CF/pH probe and meter; the nutrient solution concentration was adjusted to compensate for plant uptake. This ensured that plant nutrients such as nitrogen were always surplus to plant requirements and would not limit watercress growth during the trial. A CF of 15 was maintained. Hydroponic Solution was analysed weekly for nitrate-nitrogen using a RFA-300 (Rapid Flow Analyser from Astoria-Pacific International, Clackamas, Oregon, U.S.A.).
Each week, 10 plants were randomly selected and analysed for dry matter and total nitrogen (TN). Plant material was segregated into leaves, stems and roots and oven dried at 65°C for 3 days prior to weighing to determine dry matter.

TN was determined using a LECO Truspec C/N analyser. Representative sub-samples of plant material were sieved to <2 mm diameter and oven dried for 14 hours at 60°C prior to TN analysis.

Table 1 Hydroponic Feed Solution

Solution A (200 L)		Solution B (200 L)	
Calcium Nitrate	30 kg	Potassium Nitrate	10 kg
Potassium Nitrate	5 kg	Magnesium Sulphate	15 kg
Ammonium Nitrate	500 g	Mono-potassium phosphate	4 kg
Iron Chelate –EDTA	384 g	Potassium Sulphate	4 kg
Iron Chelate –DTPA (6%)	416 g	Manganous Sulphate	100 g
		Zinc Sulphate	28 g
		Copper Sulphate	12 g
		Boric Acid	50 g
		Sodium Molybdate	2.5 g

Figure 1A:

Watercress growing hydroponically at 28 days

Figure 1B:

Watercress growing hydroponically at 42 days

Results

Plant Dry Matter and TN Uptake

The distribution of TN throughout the plant was not uniform. The TN content was highest in the leaves and least in the roots (Figure 2).

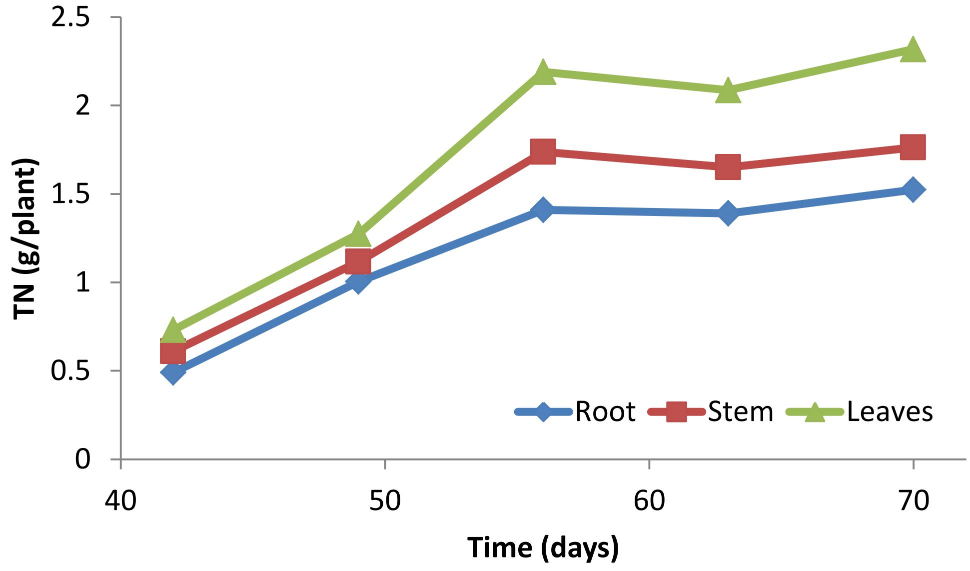

Figure 2: Total nitrogen (TN) content in watercress plant leaves, stems and roots from Days 42 to 70 (each data point is the average of 10 plants).

Plant dry matter and TN content both increased in a similar, exponential manner between Days 28 and 56 (Figure 3).

The rate of increase in plant mass and rate of nitrogen uptake slowed after Day 56. However, TN mass continued to increase as plant biomass increased. As long as the plant was actively growing, it took up nitrogen (Figure 3).

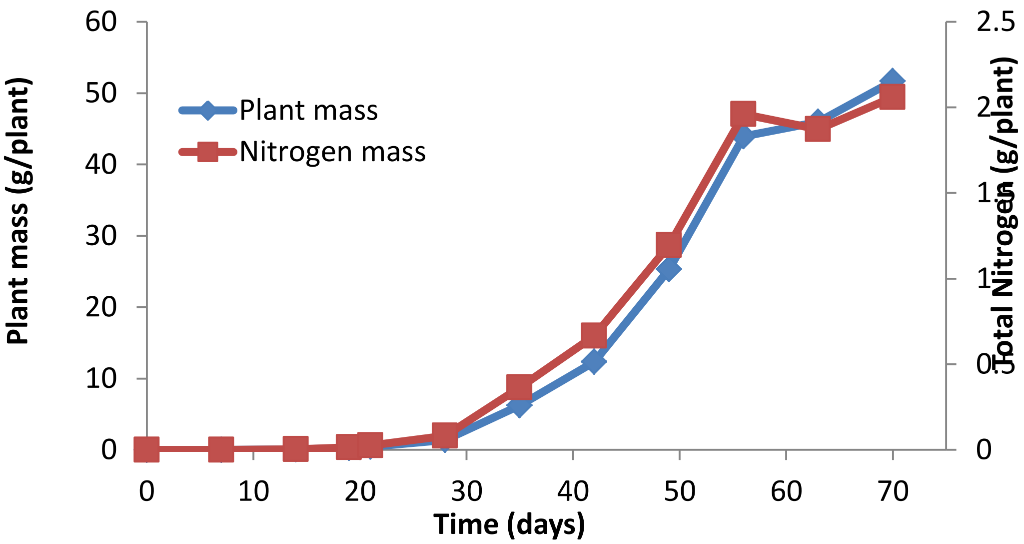

Figure 3: Change in total watercress plant dry mass (g/plant) and plant total nitrogen (TN) mass (g TN/g total plant mass) over the 70 days (average of 10 plants per data point).

Leaf TN concentration peaked at 6–7% at Day 21, and slowly decreased to just over 4% on Day 70 (Figure 4). Howard-Williams et al. (1981) also reported TN concentrations > 4% of the leaf dry mass, which is considered high for a plant.

After Day 56, the mature watercress plants had absorbed approximately 2 g nitrogen per plant (dry matter was 42 – 46 g per plant).

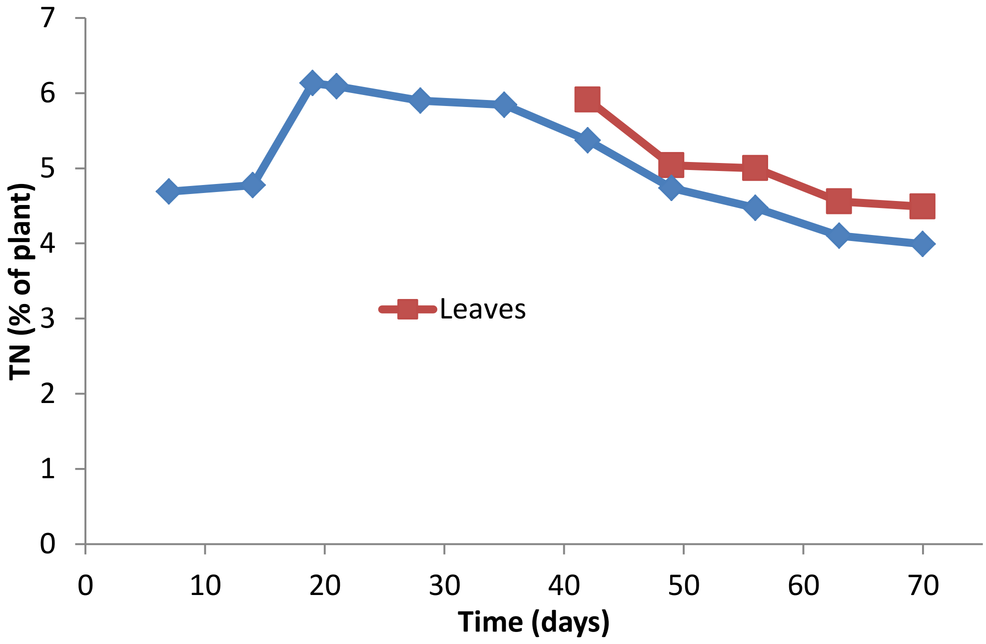

Figure 4: Total nitrogen (TN) content in watercress leaves and in the whole plant. Measurements compare %TN in plant mass from Days 0 to 70 (average of 10 plants per data point).

Discussion

Many rivers and streams are polluted by excessive nutrients. The Parliamentary Commissioner for the Environment stated that "… once nitrogen is leached to the environment there is no effective way to remove it – it is simply too late, and the consequences must be dealt with" (PCE, 2004). However, the findings of this research support the proposal that watercress could be useful to reduce nitrate levels in polluted waterways.

As watercress is an edible salad herb, it could be harvested for human consumption, stock feed or used as a compost to form nutrient-rich fertiliser. Any of these options would allow the nitrate to be completely removed from the waterway.

To maximise TN removal, watercress should be harvested when the rate of nitrate uptake is at its maximum. In this experiment, this was around Day 32. This date was based on an assessment of the derivative of the curve Figure 3. However, if plants are left to mature before harvesting, nitrogen toxicity could be an issue if used for stock or human consumption. Alternatively, leaves high in nitrogen could be used as nutrient-rich compost.
This study needs repeating in field conditions in polluted waterways.

Conclusions

Watercress is an aquatic plant with the potential to grow rapidly in water and to take up large amounts of nitrate. We found the tissue TN concentration exceeded 4% during the active growth phase of the watercress.

Watercress may therefore be an ideal plant to use to reduce nitrogen pollution in waterways, and there might even be business opportunities through the sale of the plant material.

Watercress plants could therefore provide a sustainable means to remove nitrogen from waterways, reducing the deleterious consequences of nutrient pollution.

Acknowledgements

Massey University: Russell Death, Bob Toes, Ross Wallace Steven Ray, Lindsay Sylva, Lesley Taylor, Ewen Cameron and Peter Kemp; Hawke's Bay Regional Council: Ian Millner; AgResearch: Keith Betteridge; Manawatu Science and Technology Fair Committee: Catherine Bradley; Royal Society of New Zealand: Carol Pound; Thanks to Brad Hanson, Rosalind Robertson and Peter Robertson; Chris Dunlop, Plant & Food Research, Lincoln for analysing the hydroponic solution and plant samples.

References

Chadwick, D. H. 2010. Silent Streams. National Geographic – Water, Our Thirsty World. Vol. 217(4), pp. 116-131.

Chapin, F. S. 1980. The mineral nutrition of wild plants. *Annual Review of Ecology and Systematics*. Vol. 11, pp. 233-260.

Howard-Williams C, Davies J, Pickmere S. 1981. The dynamics of growth of , the effects of changing area on and nitrate uptake by watercress Nasturtium officinale R. Br. in a New Zealand stream. Journal of Applied Ecology 19(2): 589-601.

Morgan J. & Burns, K. 2009. Manawatu River 'among worst in the West'. The Dominion Post, November 26.

NIWA (National Institute of Water & Atmospheric Research). 2008. Watercress: one step to cleaner waterways? Accessed 23/08/2009. Retrieved from: http://www.niwa.co.nz/our-science/freshwater/publications/all/wru/2008-28/watercress.

PCE (Parliamentary Commissioner for the Environment). 2004. Growing for good, Intensive farming, sustainability and New Zealand's environment. Accessed 15/07/2011. Retrieved from: http://www.pce.parliament.nz/assets/Uploads/Growing-for-Good.pdf.

Smith, V. H., Tilman, G. D., Nekola J. C. 1999. Eutrophication: impacts of excess nutrient inputs on freshwater, marine, and terrestrial ecosystems. Environmental Pollution, Vol. 100, pp. 179-196.

Sorrell, B. 2010. Chapter 8 Nutrients. In: (Eds) Peters, M. & Clarkson, B. Wetland restoration: a handbook for NZ freshwater systems. (Landcare Research), pp. 101-122.

Vincent W. F, Downes M. T. 1980. Variation in nutrient removal from a stream by watercress (*Nasturtium officinale* R. Br.). Aquatic Botany 9(3): 221-235.

Young, R. G. 2009. Hearings on submissions concerning the proposed one Plan notified by the Manawatu-Wanganui Regional Council. Section 42A. Report of Dr Roger Graeme Young on behalf of Horizons Regional Council.