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Inhibitory effect of barley straw on algal growth

Key external stakeholders:

Farmers and land-owners, water managers, fresh water scientists.

Practical implications for stakeholders:

Barley straw can be an effective low cost method for controlling problematic algal growth on lake systems, however, strict protocols in relation to preparation and location of straw booms should be adhered to in order to ensure optimal water quality and ecological results.

The key to unlocking the algal inhibitory capabilities of barley can be obtained by using specific barley strains, commercially available algal assays and modern investigative techniques.

Main results:

In order to control the growth of problematic algae in eutrophic surface waters the following recommendations should be followed:

- Optimal rates of barley addition are 10 g m^{-2} and 25 g m^{-2} (lake surface area) in areas with average and severe algal problems respectively.
- To facilitate the even distribution throughout the water system of the compounds which prevent algal growth (i.e. algistatic compounds) derived from barley, a number of loosely packed straw booms of varied length should be randomly located throughout the target water system.
- Installation of straw booms should occur in April, before the peak algal growing season.
- Prevention of algal growth may result in an increase in the growth of other aquatic plant species. This is due to increased light penetration in the water system.

The key to unlocking the algal inhibition properties of barley lies in the protocols used in laboratory experiments. A review of the literature highlighted a number of inconsistencies in the barley variety used, algal species tested, barley liquor preparation and phenol extraction methodologies. This led to differences in the growth responses for the same species of algae tested. This project highlighted several successful forms of investigation:

- using commercially available compounds i.e. with known shikimate pathway producing phenols and acids, which can then be combined with algal assays of different algal species
- using commercially available algal species from which batch cultures are grown, which are then added to barley liquor of different ages.
- using in-vivo fluorescence whereby the filtrate can then be analysed via HPLC/MS.

The identification of allelochemicals, which range from phenolics to quinones within the Poaceae family is extremely important for determining the optimal algistatic properties of compounds.

Opportunity/Benefit:

Interested stakeholders can liaise with the project researcher to develop laboratory and field protocols for successful inhibition of algal species using barley.
There is a commercial opportunity here to develop barley liquor as a viable product to prevent algal growth on surface waterbodies.

Collaborating Institutions: None

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External collaborators: None

1. Project background:

Declining ecological water quality in freshwater ecosystems has been linked to an increase in planktonic algae growth, cyanobacteria and higher forms of macrophytes. The use of organic and inorganic fertilisers and soil test phosphorous can result in incidental losses to a surface waterbody. Such nutrient losses can result in surplus nutrients being washed into waterbodies, ultimately providing suitable conditions for excess growth of algae, cyanobacteria and macrophytes. These water systems can become eutrophic, i.e., rich in nutrients and capable of supporting dense plant populations. When the dense plant populations decompose, they use up oxygen in the water column, resulting in a lack of oxygen for freshwater flora and fauna, and ultimately resulting in a reduction in biodiversity and water quality.
The Water Framework Directive stipulates that waterbodies in the Republic of Ireland must achieve "Good Ecological Status" by 2014. Currently however, 14% of the Republic of Ireland's land area has been determined to be of "poor" status, i.e., the groundwater bodies exceed the annual median phosphate concentration of 30 µg L^{-1} molybdate-reactive phosphorus (cited as the limit to prevent eutrophication in surface waters).
Slow abatement occurs in many lake systems, due to internal nutrient loading of the lake system and because many lake ecosystems can often be resistant to improvement measures. A number of studies have been undertaken in recent decades to investigate the inhibitory effect of compounds derived from barley straw on algae. Experimental set-up and outcomes have varied between studies.
The aim of the current research was to undertake a small field study to determine optimal barley application rates and appropriate construction and placement of barley booms in a water system. A second aim of the project was to compare the methodologies used in previous national and international algal inhibitor studies in order to identify optimal application rates and laboratory preparation methods.
The final aim of the study was to propose a way forward to achieve a better understanding of the inhibitory capabilities of barley on algal growth.

2. Questions addressed by the project:

- What are the optimal application rates, construction methods and placement of barley booms to prevent excess algal growth in eutrophic surface waters?
- Investigate the causes of algal inhibition by barley in the field and laboratory respectively? What are the differences in methodologies used in previous algal inhibitor studies?
- What are the gaps of knowledge that need to be addressed in order to achieve a better understanding of the inhibitory capabilities of barley on algal growth?

3. The experimental studies:

- A field experiment utilising the three artificial lakes at Johnstown Castle.
- A review of all available literature regarding algal inhibition using barley.

4. Main results:

The amount of straw to place on a lake is dependent on the severity of the algal problem and the flow within the lake. The minimum quantity of barley should be 10 g m^{-2} (surface area of lake) with a rate of 25 g m^{-2} in areas with severe algal problems. It is important to note that overloading the lake with barley can also cause environmental and ecological problems. The micro-organisms which colonise the decomposing straw absorb oxygen from the surrounding water. If too much straw is added, it can increase the demand for dissolved oxygen and lead to de-oxygenation of the water column resulting in loss of freshwater flora and fauna. For a specific case study in Johnstown Castle, taking the surface area and the flow of water through the lake into account, coupled with the severity of the algal problem, a rate of 25 g m^{-2} was deemed appropriate.

The most appropriate method of adding barley to a lake is to create a number of straw booms and place them in a variety of locations throughout the lake. This method allows for a greater dispersal of algistatic compounds from the straw. Furthermore, this method allows specific areas of problematic algal growth to be directly targeted. Constructed straw booms are more loosely packed than conventional barley bales; therefore they undergo decomposition at a faster rate and result in earlier dispersal of algistatic compounds.

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Round straw bales (weighing on average 170 kg per bale) were rolled out on mesh netting. This netting was used to loosely wrap the straw. Floats were incorporated within the straw at regular intervals to ensure that the straw would remain afloat and therefore undergo aerobic decomposition. Each bale resulted in 9 to 12 cylindrical booms, 10 to 20 m in length. These straw booms were then placed at a distance of 15 to 25 m from each other on the lakes and anchored at one end. This allowed the straw booms to move with the wind and currents and hence, increase the area affected by the released algistatic compound. Smaller straw booms (1 to 3 m) were placed in areas with particularly severe algal problems, e.g., areas around islands and areas of stagnant water.

A lake system follows seasonal trends, with phosphorous and nitrogen becoming limiting at different times. This cycle occurs naturally, but can be altered slightly following barley bale installation. With an increase in the size of the lake, the effect of phosphorous limitation is delayed. In addition, the barley booms act as sediment traps and water breakers, which improve the turbidity of the lake system. It should be noted that barley bale amelioration methods alone will not be sufficient to control problematic algal growth in water-systems that have received high nutrient inputs over a prolonged period of time. If such instances occur, it is recommended that some mechanical control measure be undertaken first to remove the nutrients, e.g., dredging. Barley bales may then be used as an on-going control measure.

A direct result of appropriate barley bale installation is a reduction in the growth of algae, along with an improvement in the turbidity of the water column. This can result in more light being available for aquatic plants to grow and prosper. In many artificial lake systems, introduced plants such as Canadian Pondweed, *Elodea Canadensis*, are common. In the present study, the prevention of algal growth afforded pondweed an opportunity to dominate the water column. It is important to note that pondweed dominance does not necessarily have negative environmental implications, however, if pondweed dominance occurs in water-systems that are open to and used by the public, problems may be encountered from an aesthetic point of view, and in relation to pursuits such as fishing and boating.
Barley bale amelioration on its own will not affect the trophic status of the lake. If a lake was previously considered to be eutrophic (e.g. containing a high nutrient content), this will still be the case, unless issues in relation to the nutrient cycling within the lake are tackled.
The positioning of barley booms is also highly important. The booms may interrupt the natural flow of the water system which in turn can have either positive or negative implications. Barley booms may result in water flow being directed to areas that previously were stagnant thus improving water quality. Alternatively, it may result in the channelling of the water flow through the lake system. This can result in large areas of the lake receiving a reduced flow of water and as such lead to them becoming more stagnant and thus giving rise to problematic species such as algae.

Many field and laboratory studies have attempted to explain the inhibitory effect of rotting barley on algae. Such studies offer practical information on barley bale field construction and application rates. However, early field studies lacked controls and replication and results typically depended on subjective visual observations and therefore discrepancies occurred. In the laboratory, discrepancies occurred between studies, particularly in relation to the barley variety used, algal species tested, barley liquor preparation and phenol extraction methodologies. Inconsistencies have led to different growth responses for the same species of algae tested, i.e., with some studies finding an inhibitory response and other studies reporting an accelerated growth response of algae.

Two successful forms of investigation have been identified:
a) using commercially available compounds, i.e., with known shikimate pathway producing phenols and acids, which can then be combined with algal assays of different algal species and,
b) using commercially available algal species from which batch cultures are grown, which are then added to barley liquor of different ages.
Algal growth may then be investigated using in-vivo fluorescence and the filtrate can be analysed via HPLC/MS. The identification of allelochemicals, which range from phenolics to quinones within the Poaceae family of which barley is a member, has received a lot of attention in recent years.

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5. Opportunity/Benefit:

Further research or co-operation with a commercial company is needed to create species-specific barley liquor to limit growth of specific problematic algal species.

6. Dissemination:

Main publications:

Fenton, O. and Ó hUallacháin, D. (2012). Growth of third generation biomass (microalgae) for biofuel production using agricultural nutrient surpluses: a review. *Algal Research*, Vol. 1, 49-56.

Ó hUallacháin, D. and Fenton, O. (2010). Barley (Hordeum vulgare) induced growth inhibition of algae: A review. *Journal of Applied Phycology*. Vol 24, 651-658.

Ó hUallacháin, D. and Fenton, O. (2011) 'Barley as a method of Algal control' in *Barley: Production, Cultivation and Uses*. Eds. Steven B. Elfson. (14pgs).

Popular publications

Ó hUallacháin, D. and Fenton, O. (2008). Artificial lake amelioration: implications for submerged aquatic vegetation, *18th Irish Environmental Researchers Colloquium,* Dundalk, February, 2008.

Fenton, O., Hyde, B., Ó hUallacháin, D., Healy, M., Regan, J., Rodgers, M. (2008). Tackling nutrient loss head on: catching the nutrients that got away, *TResearch*.

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