

Barley straw for algae control – Phase II
Agricultural Research Foundation, Final Report, 2005

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Executive summary:

Our research on the algistatic properties of barley straw was prompted by an increasing number of queries. The most frequently asked questions were: “Does barley straw really control algae?” and “How does barley straw control algae?”. With support from the Agricultural Research Foundation we’ve searched for answers to the first question with the goal of providing new markets for Oregon farmers. Specifically, our research efforts are aimed at (1) testing the efficacy of barley straw under Oregon field conditions and (2) designing an assay for testing various straw preparations on different species of algae. The first objective was prompted by the fact that while there are numerous reports, mostly from the 1990’s, on the effectiveness of barley straw for algae suppression in England, Scotland, and Ireland, there are mixed reports from the U.S. Two considerations prompted the second objective: (i) reports that barley straw, if algistatic, may not be equally effective on all algae species, and (ii) the consideration that barley varieties differ in grain quality and therefore probably also differ in straw quality and composition. Objective 2 thus inevitably leads to research on the mechanism(s) by which barley straw suppresses algae. As detailed in the following report, we still cannot provide a broad endorsement for the effectiveness barley straw for algae control, nor can we explain its mode of action. However, we have made considerable progress, thanks to the ARF support, and we will continue the research project for another year with support from the Oregon Garden SPROUt program. Please see our Barley Straw website - <http://www.barleyworld.org/barleystraw.php> – for more detailed information.

Introduction:

There is a fairly extensive literature on the use of barley straw for algae control. A full review is posted at our website: <http://www.barleyworld.org/barleystraw.php>. Key points from this literature:

- When barley straw is reported to control algae it is under the following conditions: partial submergence in water (e.g. some exposure to light is necessary) and decomposition under aerobic conditions (e.g. straw breakdown under aerated conditions is necessary).
- Barley straw has been used with some success in England, Scotland, and Ireland to control several species of algae in ponds, canals, and lakes.
- In the U.S. there are conflicting reports on the efficacy of barley straw to control algae species in large bodies of water.
- In field and lab tests, decomposing barley straw, and/or straw extracts/infusions show varying levels of control of different species of algae and cyanobacteria (blue green algae).
- The two principal hypothesized modes of action relate to the two principal components of straw: lignin and cellulose.
 - The breakdown products of lignin include a host of compounds (tannins, phenolics, and hydrogen peroxide) that are known to have algistatic properties.
 - The digestion of complex carbohydrates to simpler sugars provides carbon - a nutritional substrate for competing microbes and/or algae predators.
- Barley straw is not harmful to non-target organisms in aquatic ecosystems – e.g. higher plants, invertebrates, amphibians, fish, and birds.
- Barley straw is marketed in the U.S. for algae control at incredible prices: typical values are \$10.00 per ounce for a pre-packaged floating delivery system for small ponds to \$40.00 per 40 lb. bale for larger-scale deployment.
- Barley straw is not an approved EPA-approved pesticide.
 - It is possible to obtain experimental use permits for application of barley straw to public waters in the state of Oregon.

Research Results

Efficacy of barley straw under Oregon field conditions

Our two principal test sites are the Oregon Garden and the J.F. Schmidt and Son nursery. At the former we have focused on the “Amazing Water Garden” feature and at the latter we have focused on the Barlow Reservoir. These sites were selected as being representative of an ornamental water feature and a commercial irrigation installation, respectively.

Oregon Garden

Site: The Amazing Water Garden (AWG) is a centerpiece for visitors to the Oregon Garden. The AWG with its 8 cells, has a volume of 150,000 gallons. Water is re-circulated in the AWG and makeup water is added to compensate for evaporation and seepage loss.

The problem: Filamentous algae growth both in the individual cells of the AWG and in the trough and face of the waterfall are aesthetic issues. The algae growth led the Oregon Garden Staff to use various treatments including skimming, power washing, and hydrogen peroxide.

Straw treatments: The waterfall was first dosed with barley straw in June of 2004. In summer of 2004 both barley straw and hydrogen peroxide were used, along with shutting down flow of the waterfall on Tuesday evenings and drying out the algae on the rock face. In 2005, barley straw, totaling ~200 pounds, was first added to the cell by the waterfall. On March 8 four bales @ ~40 pounds each were positioned under the bridge. On April 15 these bales were pulled from beneath the bridge and repackaged with an additional bale as straw “sausages” in jute fabric and placed at intervals in the trough above the water fall. During the week of June 13 an additional 40 pounds of straw sausages were added to the trough.

Algae species characterization and relative abundance: The floating, drifting, and rock-adhering algae in the AWG were characterized in March, at the time of first straw deployment, and on June 8. The same sampling sites were used at both dates. Taxa of algae are broadly separated on the basis of dominant plant pigments and then various morphological features. In late March green algae (Chlorophytes) dominated the algae in cells of the AWG: a small colonial taxon *Pediastrum bornyaum*, large filamentous greens including *Spirogyra* sp., *Oedogonium* sp., *Cladophora glomerata* (the primary rock wall nuisance) which form flocculant and very visible masses on cell bottoms and surfaces, and a small filamentous green *Hormidiopsis* sp. Other minor but abundant groups were the diatoms (a variety of species that live within glass cell walls) many of which live on or amongst the larger green algae: *Fragilaria construens*, and *Gomphonema truncatum*. The Cyanobacteria were present but small and much less prominent within the algae in the cells.

In early June, with higher temperatures, *Rhizoclonium hieroglyphicum* (which was present end of March), *Hydrodictyon reticulatum* and *Spirogyra* (each robust green algae species) were common to abundant and visible in the cells. *Pediastrum* continued to be abundant but still of minor aesthetic impact since it is small relative to other larger filamentous greens. The diatom *Fragilaria construens* continued to be abundant and the Cyanobacteria continued as insignificant. By late June the filamentous algae had proliferated in cell A (adjacent to the waterfall in AWG) and some flocculant masses had to be removed via skimming.

Water quality: The robust filamentous algae that are in the AWG and in cells above and below the AWG (Complex A and Complex C, respectively) are typical of waters with high concentrations of nitrogen and phosphorus. The water quality data generated by the City of Silverton waste water treatment plant (WWTP), that delivers ~0.5 mgd to Complex A above the AWG, and the water quality data that has been generated by OG staff, were tabulated for this report. Phosphorus concentrations for 2004, and so far for

2005, have been 1.8 and 2.3 mg/l. Nitrogen concentrations in water used to irrigate the garden and provide make-up water for the AWG are similarly high.

Summary and interpretation of data:

- Oregon Garden staff were favorably impressed with the effects of straw from the time of application until early June. No algae control measures were implemented until late June of 2005. In previous years, control measures had to be applied much earlier in the season.
- Since June, *Rhizoclonium*, *Hydrodictyon* and *Spirogyra*, each robust green algae species, have proliferated with higher summer temperatures, requiring skimming of the waterfall cell.
- The proliferation of *Azolla*, a small floating fern, probably restricted algae growth through shading during spring competing with the algae for plant nutrients, and with turning off the waterfall Tuesday evenings, filamentous algae growth was reduced.
- Without replication it is difficult to know if algae growth in the AWG would have been different without the barley straw application.
- The very high phosphorus and nitrogen content of water entering the Oregon Garden from the Silverton sewage treatment plant will stimulate algae growth and may override the effects of barley straw decomposition products. This will complicate the interpretation of barley straw application, as well as provide a challenge for selecting suitable alternative control measures. The literature on eutrophication of lakes and rivers notes the likelihood of nuisance algae growth above 0.05 mg/l: the average total phosphorus concentrations at the Oregon Garden are ~ 40 times higher than this threshold. This high nutrient load challenges the OG to make good use the plant nutrients that come to the Garden via the WWTP. Normally phosphorus is the limiting nutrient in freshwater aquatic systems; reduce phosphorus concentrations and plant biomass will be reduced.

Long-term perspectives and future plans:

- The principal challenge for barley straw assay at the Oregon Garden, and in all field tests, is the lack of options for replication and control treatments. Our alternative strategy is to characterize species structure and relative abundance over the season in the AWG and in cells above and below the AWG. These data are currently being analyzed.
- On the basis of promising results from controlled environment tests (see below) using a mixture of filamentous algae and diatoms from the Oregon Garden, an expanded assay using the most abundant filamentous green algae (*Spirogyra*, *Rhizoclonium* and *Hydrodictyon*) from the Oregon Garden will be conducted in July at OSU. We will infusions from barley straw decomposing in Oregon Garden water, and straw directly added to Oregon Garden water with the algae.
- As noted in the previous section, the very high phosphorus and nitrogen content of water entering the Oregon Garden from the Silverton sewage treatment plant will stimulate algae growth and may override the effects of barley straw decomposition products. This will complicate the interpretation of barley straw

application, as well as provide a challenge for selecting suitable alternative control measures

- The negative reactions to algae, duckweed [*Lemna*] and Azolla growth are driven by the aesthetics of the observers. Those who love algae and know the beauty and diversity of algal assemblages from microscopic inspection are not overly bothered by the algae growth in the Garden. This, however, is a very small number of the people who visit the Garden.
- An integrated approach involving nutrient management, education on the benefits of algae, and intensive aquatic ecosystem management will be required in order to achieve the competing objectives of biofiltration and horticultural aesthetics.

J.F. Schmidt and Son Nursery

Site: The JFS irrigation reservoir (Sunset Center Pond) at the Barlow farm covers 1.1 ac with a volume of approximately 5 acre ft, There are four wells from which water is variously drawn to supply the reservoir during the irrigation season. The water of the wells differ in the quantity of nitrogen and phosphorus. Filling of the reservoir for irrigation began toward the end of June.

The problem: Algae blooms have complicated water filtration and irrigation, and are an aesthetic issue.

Straw treatments: The reservoir has been dosed with barley straw for the past two years. Approximately 390 pounds of straw (application rate of 28 gm/cubic meter) was deployed April 13, 2005 in (2x2x6-8 ft) wire mesh containers beneath 8 pvc float tubes with ropes to weights to keep them floating within limited areas of the reservoir.

Algae species characterization and relative abundance: Prior to straw deployment, the algae in the reservoir was characterized in a late March sampling of the water, sediment with emerging *Potamogeton*, surfaces of aeration hose on reservoir bottom, and debris on reservoir bank from fall 2004 skimming of algae from surface. The algae was dominated both in water and in the sediment by a large diatom *Navicula cuspidata*, and on the surfaces of the aeration hoses and presumably on sediment by this diatom and a filamentous Cyanobacteria *Oscillatoria agardhii*. The diversity of algae in the reservoir in water and on surfaces was high with 11 taxa of diatoms, one flagellated golden alga, 9 taxa of green algae, 2 Cyanobacteria and 2 Cryptomonads. In June, the diversity of algae observed from the water and surfaces within the reservoir was higher than March. There were 12 species of diatoms, 12 species of green algae, four species of Cyanobacteria, and one species of Dinoflagellate. The most abundant species in the reservoir water was a small species of *Scenedesmus* (green algae). The more robust filamentous green alga (also observed at the Oregon Garden), *Rhizoclonium hieroglyphicum*, increased its presence near the submerged, rooted aquatic plant (*Potamogeton* sp.) 4 – 6' from the shoreline. Anecdotally, *Rhizoclonium* also proliferated in 2004 and had to be skimmed from the reservoir. While its presence is noted in sample results, it has not yet become abundant and a nuisance.

Replicated tests simulating a pond environment: As with the Oregon Garden tests, the challenge at the Barlow pond is lack of replication and control treatments. At this site, we attempted to create an experimental system using four 150 gal stock tanks installed near the reservoir. In April, the tanks filled with the same well water used to fill the reservoir, and seeded with algae from the water, sediment, and floating algae of reservoir.

Water quality: The analysis of water from one of the wells one of the wells used to fill the reservoir resulted in total phosphorus concentrations of 1.6 mg/l and nitrate-nitrogen concentrations of 10.6 mg/l.

Summary and interpretation of data:

- Compared with conditions in years prior to use of barley (which began in 2004), this reservoir has had much less algae.
- Conditions in this reservoir were not completely satisfactory, however, as Cutrine (copper based algaecide) was used in 2004 as irrigation season progressed.
- While water clarity in the reservoir has been generally suitable for irrigation, the presence on the bottom of scattered aggregations of the filamentous algae *Rhizoclonium*, which matted on the surface of the reservoir last summer, may require treatment with Cutrine if proliferation occurs.
- Without replication it is difficult to know if algae growth in the reservoir would have been different without the barley straw application. In order to address the issue of replication, we installed four stock tanks at this site in an attempt to mimic reservoir conditions. The preliminary results are presented in this next section on *Perspectives and future plans*.
- The high phosphorus and nitrogen content of the well water for the reservoir water will stimulate algae growth and may override the effects of barley straw decomposition products. This will complicate the interpretation of barley straw application, as well as provide a challenge for selecting suitable alternative control measures.
- After 2-3 weeks algae growth increased visibly in the tanks and barley straw was added to two of the 4 tanks. Approximately 2 weeks after application, all tanks cleared with algae precipitating to the bottom of the tanks. Chemical analysis of water from the tanks and one well suggested possible nutrient depletion from dense bloom of a limited number of planktonic algae (*Scenedesmus* spp.) in the tanks.
- The analysis of the early June samples from the reservoir indicated the tanks simulated earlier the proliferation of the small green algae *Scenedesmus* spp.
- Both the tanks and the reservoir will be monitored to observe further changes that might indicate barley straw effects.

Long-term perspectives and future plans:

- The lack of replication and long-term algae species and relative abundance data complicate the interpretation of barley straw effects. Algae growth this year, as last in the reservoir, could have been much worse without the barley straw.

- Multiple sources of well water for the reservoir though indicate the tank assays will likely not simulate reservoir conditions through the summer.
- The high phosphorus and nitrogen content of water entering the reservoir favors algae growth and will complicate control measures.

Controlled environment tests

Summary of experiments:

We have continued our controlled environment assays, using decomposing straw infusions and mixed algal cultures. We have observed that straw infusions from month-old infusions of decomposing barley straw made in pond water from the Oregon Garden are more effective in controlling mixed species of algae (principally *Oedogonium* sp. and a Cyanobacteria species *Nostoc*) than an infusion made with tap water. Likewise, we have observed that the mixed algal cultures grown in Oregon Garden pond water are more vigorous and long-lived than cultures grown in tap water. We interpret these results to mean that the nutrient-rich Oregon Garden pond water is a more suitable substrate for growing algae and that it also harbors microbes that accelerate the decomposition of barley straw and consequently the production of whatever compound(s) have algistatic properties. For this reason, and due to the high nutrient levels complicating field assays at the Oregon Garden, we are using the water entering the Garden from the City of Silverton water treatment plant for all future controlled environment assays.

Long-term perspectives and future plans:

- Our future experiments will focus on assays involving the principal nuisance species at the Oregon Garden (*Rhizoclonium*, *Spirogyra*, and *Hydrodictyon*) and the Schmidt nursery (*Scenedesmus*, and *Rhizoclonium*), as well as “blue green algae” (cyanobacteria, e.g. *Aphanizomenon flos-aquae*, *Microcystis aeruginosa*, or *Anabaena flos-aquae*) that are causing health and environmental issues in n Oregon lakes. The growth chambers and greenhouse at OSU will be valuable in the further development of algal cultures and controlled, replicated assays.
- We have archived samples from the straw infusions, and from all field sites, in order to perform chemical analyses of the straw. These analyses will characterize the two principal components of straw that may have algistatic effects: lignin and its breakdown products and structural carbohydrates and their breakdown products. Lignin and breakdown products (humic acids and ultimately hydrogen peroxide) are known to have algistatic properties. As a carbon source, straw decomposition may favor microbes that out-compete algae and/or microbes that are algae predators.

Education and outreach

- Our barley straw website - <http://www.barleyworld.org/barleystraw.php> - describes our research efforts and provides links to resources on barley straw. The site is scheduled for complete updating by August 1, 2005.
- We have completed an extensive literature review of barley straw and its effects on algae, and have developed an analysis of this literature for our guidance in

continuing research on this challenging subject. This review will be made publicly available at the website.

- We participated in the Oregon Garden 2005 Earth Day event with a barley straw booth.
- We have responded to numerous enquiries regarding barley straw for algae control and have provided straw upon request.

Leveraging ARF funding

Thanks to ARF support, we were successful in competing for funds to continue our barley straw for algae control research. In 2005, the Oregon Garden SPROUt program awarded \$15,000 for our continued barley straw research.

Conclusions

We are confident in stating that barley straw may be a useful tool for control of algae but that it is not a “silver bullet”. Proper aeration, control of nutrients, and proper deployment of the correct amounts of straw are essential. Additional treatments may be necessary, and a thorough analysis of the pond/reservoir algae before and after application, along with water quality data is essential. We anticipate that at the conclusion of the SPROUt grant we will have more definitive answers on barley straw for algae control efficacy and mechanisms. The two years of funding from the ARF were essential for launching this project and we are most appreciative of this confidence and support.