EVALUATION OF BARLEY STRAW AS AN INHIBITOR OF WATER NET (*HYDRODICTYON RETICULATUM*) GROWTH.

R.D.S. WELLS, J. HALL and I. HAWES¹

NIWA - Ecosystems, Box 11-115, Hamilton

¹NIWA - Ecosystems, Box 8602, Christchurch

SUMMARY

Laboratory and outdoor tank trials showed varying degrees of inhibition of water net (*Hydrodictyon reticulatum*) growth by aerobically decomposing barley straw. One laboratory trial showed complete inhibition of growth, but inconsistencies in results, including enhanced growth were also found. Field trials using barley straw in water net affected areas did not show a reduction in water net growth of a magnitude sufficient to warrant its use. Examples of enhanced growth near barley straw bales were also recorded.

Keywords: water net, *Hydrodictyon reticulatum*, barley straw, algistatic effects.

INTRODUCTION

The rapid spread of nuisance growths of the green alga, water net, in New Zealand prompted the authors to evaluate the use of barley straw as a possible control method. Extracts of decomposing barley straw liquor have been reported to inhibit the growth of several planktonic and filamentous algae at rates of 4 and 10 kg d.wt. straw/m³ (Gibson *et al.* 1990) and as low as 2.57 g/m³ (Newman and Barrett 1993). Welsh *et al.* (1990) reported inhibition of algal growth in a canal (turnover time 5.3 h) using 440 g d.wt. barley straw/m³. As water net is seasonal, producing nuisance growths in summer from a low over-winter biomass, an algistatic agent active in spring and summer, has the potential to prevent nuisance growths developing.

The mechanism of inhibition is still largely unknown, but conditions necessary for inhibition to occur are becoming established. Aerobic decomposition of barley straw after about 1 month produces an algistatic effect. The active agent is water soluble, but of short persistence in water. Algal growth resumes when treated algae are transferred to straw-free water (Newman and Barrett 1993).

This paper outlines the approach and findings of three laboratory, one outdoor and three field trials assessing the effectiveness of barley straw in controlling growth of water net, conducted from 1991 - 1994.

METHODS

Laboratory trial 1

Two kgs of chopped barley straw (20 mm long) were incubated in 100 litres of aerated Lake Taupo (rate = 20 kg/m³) water in a black plastic tub from 4.9.91. At around monthly intervals, straw liquor was diluted with algal growth medium giving a calculated rate of straw addition for the assays equivalent to 4 kg d.wt./m³. The untreated control flasks had deionised water instead of straw liquor added. One 3 day old colony of water net was added to each of three replicate flasks with 250 ml of diluted straw liquor and incubated for 7 - 10 days at 150 μ mol photons/m²/sec and 20°C. The yield of each culture, determined as dry weight and carbon content, was compared with the untreated controls. After 9 months the procedure was repeated but with freshly diluted liquor continuously pumped through (2.3 h turnover time) the water net cultures. Yield of these continuous cultures was determined as dry weight for two replicates.

Proc. 47th N.Z. Plant Protection Conf. 1994: 368-372

Laboratory trial 2

Three month old rotting barley straw, contained in mesh bags, was added to three tanks each containing 6 litres of growth medium (at a rate of c. 40 g d. wt./m³) under the same conditions as for trial 1. A 100 µg inoculum of 3 day old water net colonies was added. Yield of water net was compared with that from similar tanks without barley straw.

Laboratory trial 3

This trial was similar to trial 1 except glass tanks were used for the decomposition of the straw and N and P were added to the decomposing straw as NO₃ and DRP respectively. Barley straw was added at a rate of 40 kg/m³ and decomposed in a 20°C aerated solution of 1 g NO₃/m³ and 0.1 g PO₄/m³ in Lake Taupo water. The straw liquor was tested for inhibition of water net growth at c. 1, 2, and 3 months, as in Lab. trial 1, except that the yield of each culture at 2 and 3 months was determined as chlorophyll *a* (µg per net), while in the one month test, dry weight was used. After 3 months the tank was allowed to become anaerobic by ceasing aeration for a month and then further tests for inhibition were conducted at c. 5.5, 7 and 8 months.

Outdoor trial

Twelve outdoor 1.5 m³ concrete tanks were filled (29.1.93) with Tauranga tap water and barley straw was added in mesh bags to give rates of 0 (control), 0.04, 0.4, and 4.0 kg d. wt./m³. Tanks were covered with shade cloth (75%) to reduce algal growth. After 16 days the 0.4 and 4.0 kg d. wt./m³ treatment had become anoxic, so these tanks were drained and replaced with treatment rates of 0.08 and 0.16 kg d. wt./m³. After 2 months the shade cloth was removed, a hydroponic solution was added to raise NO₃ concentrations to c. 3 mg/litre and an inoculum of c. 12 g d. wt. water net was added to each tank (8.4.93). All water net biomass was harvested from each tank, 21 days later, for dry weight determination.

Field trial 1 - Matata Lagoon

Matata Lagoon (Bay of Plenty) is a shallow (0.4 m), 11.6 ha water body with a turnover time of about 27 days and recent history of nuisance water net growths. In August 1991, when water net biomass was near zero, twenty gabion baskets (c. 1 x 2 x 0.75 m), filled with loose barley straw from 60 bales, were anchored in the western end of Matata Lagoon near the inflow where water net growth had been most dense during the preceding summer. The treatment rate was c. 15 g/m³ calculated for the whole lagoon. The distribution and abundance of water net in the lagoon was monitored monthly by assessing percent cover from a boat and noting distribution on sketch maps of the lagoon. Water net biomass was measured in February 1992, by collecting five quadrats (each 0.3 m²) from a high density area of water net and from an area near the straw.

Field trial 2 - Lake Aniwhenua and Bell Rd

Three bays (Sites 1, 2, and 3) in backwaters at the head of Lake Aniwhenua (Rangitaiki River, Bay of Plenty) with a history of water net infestation were selected for additions of barley straw and compared with adjacent untreated bays (controls). Site 4 was an impoundment near the lower Kaituna River (Bay of Plenty) at the end of Bell Rd and was compared with a water net site nearby (on the other side of a causeway). Gabion baskets containing loose barley straw were added to all sites on 13.10.92, to give treatment rates of c. 80 g d. wt./m³ for Sites 1 to 3 and c. 44 g d. wt./m³ at Site 4. Abundance of water net at treated and control sites was determined by sampling 0.1 m² quadrats (with a mesh bag attached) on 13.10.92 and 13.1.93 and processing them for dry weight. Initially three samples were collected from each site (treated and untreated controls), but due to difficulties with unconsolidated sediments and large quantities of organic debris mixed through the samples, only one sample from each treated site was processed. Consequently biomass results are indicative only as the sampling error was estimated to be up to 50%. The percent cover of water net was visually assessed from the surface and using SCUBA.

Field trial 3 - Lake Aniwhenua bioassays

At Sites 1 and 2 (as referred to in Field trial 2), new straw was added on 29.9.93 to give rates of c. 50 g d. wt./m³ at Site 1, and 220 g d. wt./m³ at Site 2. *In situ* bioassays

were conducted after c. 1, 2, 4, and 6 months of straw decomposition, by adding 30 g fresh weight of healthy water net (c. 1.3 g d.wt.) to each of three floating 0.1 m³ fine meshed cages per site (treated and control) and harvesting the water net for dry weight determination after 14 days.

RESULTS AND DISCUSSION

Laboratory trial 1

Water net growth was enhanced by decomposing straw at a rate of 4 kg/m³ and at no stage was inhibition of water net growth recorded (Table 1). Batch cultures may have been ineffective because of rapid decomposition of the inhibitory factor in water (Newman and Barrett 1993). To overcome this possibility the continuous addition of straw liquor (in month 9) was tested, but this also resulted in water net growth enhancement; the treatment yielded (in grams) 263% (SD+18) of the liquor free treatment. However, black plastic tanks used as containers for the decomposing straw, were later suspected of preventing inhibition, since similar effects have been noted in U.K. trials (Barrett pers. comm.).

TABLE 1: Effect of straw liquor on growth of water net. Yields (g d.wt.) are given as percentage of liquor-free control, mean $\pm$ standard deviation.

Rotting time (months)	1	2	3	4	5
Yield	318 $\pm$ 165	128 $\pm$ 30	104 $\pm$ 29	246 $\pm$ 76	138 $\pm$ 19

Laboratory trial 2

There was total inhibition of water net growth in the presence of barley straw at 40 g d.wt./m³. The untreated control tanks produced over 200 mg d.wt. from a 100 μ g inoculum while the straw treatment did not grow at all. This was the most marked algistatic effect seen in any of the trials. If this effect could be produced on a large scale in the field, it would be a very useful technique for preventing nuisance water net growths. However, interpretation of this experiment was complicated as it was found that the decomposing straw had consumed all available nitrogen in the water. Nitrogen limitation could therefore not be excluded as a cause of no growth. N and P were added to all subsequent experiments to preclude nutrient depletion effects.

Laboratory trial 3

The barley straw liquor enhanced water net growth when tested during the first 2 months of decomposition but was inhibitory after 3 months when growth was only 12% of the untreated controls (Table 2). Nutrient concentrations in the media at the end of the test confirmed that inhibition was not due to nitrogen limitation. The algistatic effect ceased following a change to anaerobic decomposition with enhanced water net growth recorded in subsequent assays (Table 2). These results confirm that barley straw can be inhibitory to growth of water net, but during early stages of decomposition and periods of anaerobic decay, enhanced water net growth can be expected.

TABLE 2: Growth of water net as a percentage of untreated controls ($\pm$ SD). Biomass was measured by chlorophyll *a* (μ g per net).

Days	32	58	90	170	209	248
Control	100 $\pm$ 13 ¹	100 $\pm$ 28	100 $\pm$ 36	100 $\pm$ 28	100 $\pm$ 24	100 $\pm$ 27
Straw	119 $\pm$ 3 ¹	126 $\pm$ 13	12 $\pm$ 8	429 $\pm$ 20	124 $\pm$ 40	145 $\pm$ 70

¹g d.wt. used to measure biomass - anaerobic decomposition

Outdoor trial

The higher rates of barley straw additions (0.4 and 4.0 kg d.wt./m³) caused anoxia in the static tanks. The 0.1 and 0.08 kg d.wt./m³ treatments decayed aerobically yet enhanced water net growth when tested from day 43 - 64 of straw decomposition. However, the lower rate (0.04 kg d.wt./m³), which was tested from day 63 - 84, was algistatic with yields being 60% of the controls (Table 3).

In comparison with U.K. trials, the decomposition time required for an algistatic effect on water net in New Zealand was at least 1 month longer under similar conditions and enhanced algal growth in early stages of decomposition was not reported in the U.K. trials (Gibson *et al.* 1990; Welch *et al.* 1990; Newman and Barrett 1993).

TABLE 3: Biomass of water net (g d.wt.) as a percentage of the untreated control $\pm$ SD in outdoor tanks with rotting barley straw.

Barley straw (kg d.wt./m ³)	Decomposition time (days)	% relative to control
Control (no straw)		100 $\pm$ 34
0.04	63	60 $\pm$ 6
0.08	43	141 $\pm$ 21
0.1	43	159 $\pm$ 6

Field trial 1 - Matata Lagoon

Water net increased in abundance throughout Matata Lagoon as water temperatures rose from October to February, with the exception of an area between 10 and 40 m from the bales of barley straw (Fig. 1). A biomass of 163 g d.wt./m² (five quadrats ranged from 141 - 184) was measured in February about 150 m south east of the straw. Water net growth within 10 m of the straw was minimal with nets too diffuse to sample for dry weight determination. Biomass was estimated to be less than 2 g d.wt./m². The distribution and abundance of water net suggested that the straw was having a localised inhibitory effect (Fig. 1).

Figure 1: The distribution and cover of water net in the Matata Lagoon in August 1991 and February 1992.

Field Trial 2 - Lake Aniwhenua and Bell Rd

At the start of the trial, cover of surface floating water net at all sites was less than 1%, but benthic cover was c. 50%. Biomass at treated sites (before straw additions) ranged from 2 g d.wt./m² to a maximum of 6 g d.wt./m². During the summer all sites produced abundant water net as seen in cover estimates and biomass values in Table 4. Only the treated plot at Site 3 was clearly different from its untreated control plot. This site was more enclosed than the others and the lack of growth was attributed to depleted NO₃ levels after they were found to be limiting with levels of <1mg/m³ measured (21.1.93) compared with all other sites which had >20 mg NO₃/m³ water.

The decomposing straw was aerobic (c. 5 mg O₂/litre) when measured on two occasions and observation of large numbers of invertebrates and eels in the straw suggested it remained aerobic throughout the trial. At all sites, other than Site 3, >80% cover of water net persisted until late June 1993. Water net formed nuisance growths at all treated sites (including Site 3) in the presence of rotting barley straw and there were no indications of an algistatic effect.

TABLE 4: The abundance of water net (percent surface cover and indicative biomass values, see methods) at Sites 1 to 4 treated with barley straw. Untreated sites are shown in parenthesis. The margin of error for biomass was estimated to be up to 50%.

Site	October 1992		January 1993	
	% cover	biomass (g.d.wt./m ²)	% cover	biomass (g.d.wt./m ²)
1	0 (0)	5	100 (100)	165
2	0 (0)	4	100 (100)	174
3	0 (0)	2	26 - 50 (100)	104
4	<5 (<5)	6	75 - 95 (75 -95)	207

Field trial 3 - Lake Aniwhenua bioassays

Barley straw enhanced growth of water net in early stages of decay at both treated sites. Enhanced growth continued over the 25 week period at Site 2. At Site 1 growth was inhibited at 8 - 10 weeks with maximum inhibition (72% of untreated control) recorded during the 16 - 18 week assay (Table 5). Despite this algistatic effect, the reduced growth rate of water net still produced a 533% increase in dry weight of inoculum in 2 weeks.

TABLE 5: Growth of water net as a percentage of untreated control $\pm$ standard deviation using g dry weight as measure of biomass.

Weeks	4	8	16	23
Site 1	126 $\pm$ 8	84 $\pm$ 7.4	72 $\pm$ 0.9	79 $\pm$ 12.9
Site 2	139 $\pm$ 8.9	603 $\pm$ 11.4	144 $\pm$ 21.6	108 $\pm$ 32

In field trials the results were inconsistent and, at best, algistatic effects were not of sufficient magnitude, nor did they affect a large enough area, to be useful in preventing nuisance growths of water net developing. Enhanced growth of water net by barley straw in early stages of aerobic decomposition and during anaerobic decomposition, is of sufficient concern for the authors to recommend, that barley straw is *not* used for water net control.

ACKNOWLEDGEMENTS

Field assistance and materials were provided by Environment BoP, and R. Smith and A. Taumoepeau (NIWA) provided technical assistance.

REFERENCES

- Gibson, M.T., Welch, I.M., Barrett P.R.F., and Ridge, I., 1990. Barley straw as an inhibitor of algal growth II: laboratory studies. *J. App. Phycol.* 2: 241-248.
- Welch, I.M., Barrett, P.R.F., Gibson, M.T. and Ridge, I., 1990. Barley straw as an inhibitor of algal growth I: studies in the Chesterfield Canal. *J. App. Phycol.* 2: 231-239.
- Newman, J.R. and Barrett, P.R.F., 1993. Control of *Microcystis aeruginosa* by decomposing barley straw. *J. Aquat. Plant Manag.* 31: 203-206.