ALGAL BIOMASS HARVESTING FROM THE INTEGRATED ALGAL PONDING SYSTEM (IAPS) FOR HORTICULTURAL NUTRIENT ENRICHMENT

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ABSTRACT

Water and food research are priorities for government. Addressing hunger and malnutrition together with water and sanitation is a cost-effective way of improving social welfare, but also promotes sustainability in water utilisation and agriculture. The provision of adequate water and sanitation as well as job creation are issues faced by smaller towns in South Africa and particularly in areas such as the Eastern Cape. These issues can be addressed simultaneously by water recycling, reuse, residue utilisation and waste beneficiation. The Integrated Algal Ponding System (IAPS) has been developed as low-cost yet highly effective wastewater treatment process. This treatment system also presents opportunities for production of value-added products from the algal by-product. The residual algal biomass contains nutrients which provide a basis for downstream beneficiation applications such as horticulture, community gardens or high-value foliar feeds. The integration of these factors has the potential to change the economics of small wastewater treatment plants from purely utility value to include opportunities for social development and job creation. This paper details the investigation of this application of algae from the IAPS water treatment process in horticulture as part of a Water Research Commission funded project.

INTRODUCTION

Sustainable Development, Poverty Alleviation and Nutrient Cycling

Access to water and sanitation is a core consideration in the drive for sustainable development [1] and the lack of access to water resources can be seen as “an ultimate poverty”, [2]. Challenges facing the eradication of poverty and sustainable development include “recycling of wastewater nutrients, wastewater irrigation and urban agriculture” [2]. The management of small sewage treatment works (STWs) has been identified as problematic due inadequate attendance to technical, social and institutional issues [3 & 4]. These are major causes of system failure which threatens the sustainability of STWs in most small towns [3]. This situation is prevalent in the South Africa, particularly in the Eastern Cape where approximately 74% of all STWs are small (<1 Ml/day) [4]. The model developed by Murray *et al* [3] for small water treatment systems is equally applicable to STWs and demonstrates inter-related nature of sustainability and that the consequences of poor management are escalating ecological and socio-economic impacts (Figure 1). Poverty constitutes a major barrier to direct cost recovery, leading to unsustainable service provision [5]. Thus a different approach to cost recovery is needed. Potential ways of recuperating costs from STWs include: water recovery for irrigation or industrial use, biogas recovery, processing organic matter to methane for electricity [6, 7] and sale of sludge to farmers or brickmakers [8]. However, not all these options are feasible or appropriate to rural areas or developing countries [6]. The emphasis has to be on simplicity. Only by combining waste beneficiation with simple treatment technologies, can STWs become more sustainable without burdensome high-tech or costly infrastructure [9]. An alternative to cost recovery mechanisms is to opt for suitable low-cost, low-technology yet effective wastewater treatment.

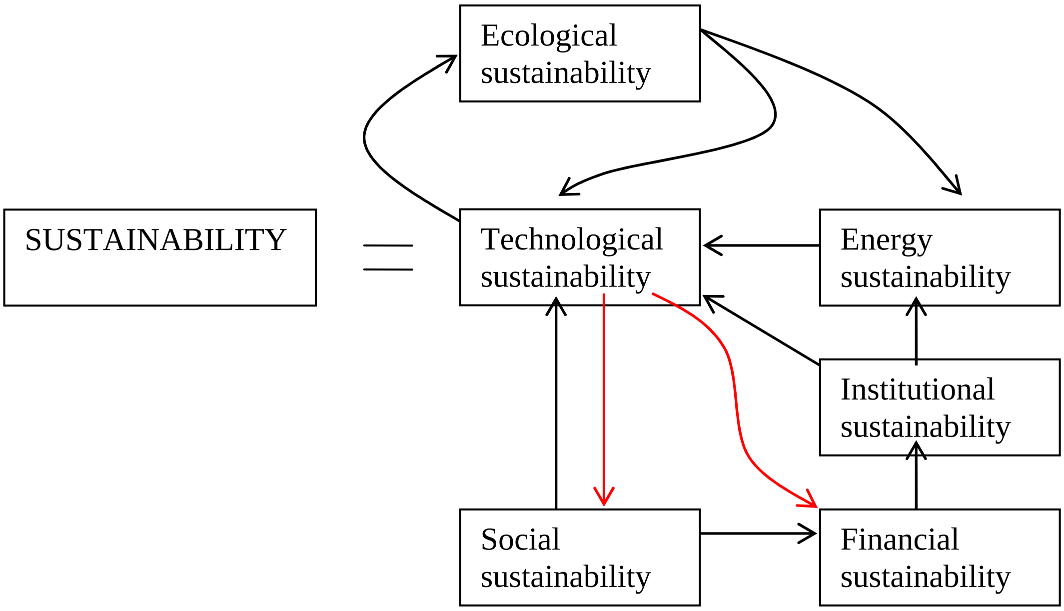

Figure 1. Interactions between the components of sustainability [3]. Red arrows indicate where IAPS can increase social and financial sustainability.

The IAPS as a Resource Recovery System

The Integrated Algal Ponding System (IAPS) is a low-cost, low-technology wastewater treatment system which has the potential to add another dimension to the technological, social and financial sustainability of a wastewater treatment system [10]. An IAPS pilot plant has been constructed at the EBRU Field Station at the Grahamstown Disposal Works in the Belmont Valley, Grahamstown [10]. The IAPS consists of an anaerobic fermentation pit; a primary facultative pond; 1 or 2 High Rate Algal Ponds (HRAPs) and algal settling ponds to remove suspended algae from the water before discharging. HRAPs are designed to optimise algal growth by maximising light penetration while keeping algae in suspension. Nutrients are taken up by the algae and high pH and UV penetration induces high pathogen kill rates. The IAPS thus produces high quality effluent which can easily exceed discharge standards without the need for quaternary treatments such as chlorination. Incidentally the IAPS produces algal biomass as a potentially valuable by-product [10] as opposed to sludge produced by most conventional systems [11]. The HRAP as a component of the IAPS can also be retrofitted to existing STWs as a tertiary treatment system (Independent High Rate Algal Pond, I-HRAP) to polish effluent of treatment works not achieving adequate treatment levels due to overloading or other problems [12]. The potential that exists in terms of I-HRAP or full IAPS is to change a STW from purely utility value of sewage treatment to a resource recovery system through the recycling of water for downstream horticulture or agriculture, and additionally through the beneficiation of the algal by-product into fertilizer or other forms of plant growth stimulants.

Figure 2 One of the High Rate Algal Ponds at the EBRU field station, in which algae grows, taking in nutrients and raising the pH

The use of the algal by-product of the IAPS as a resource in agriculture and horticulture is the focus of this study. Although much work has been done on the use of seaweed in horticulture and agriculture for soil amendment, fertiliser and foliar feeds, little has been reported on the use freshwater micro-algae from sewage treatment systems [13]. Anecdotal evidence of the potential of IAPS algae prompted further investigation into IAPS algae as a basis for waste beneficiation.

In 2004 an experimental site was set up on Chamissonis Farm, near Grahamstown, Eastern Cape. The purpose of this study was to get gather data on the soil amendment properties of the algal sourced from the IAPS. The trial conducted showed good results as are shown in figure 3.

Figure 3 Results of field trials undertaken in 2004 using algae as a fertilizer with Swiss Chard


Figure 4 Shows a picture taken of three turnip crops given three different treatment of (from left to right) fertilizer, algae and algae-fertiliser.

These results warranted a more controlled experiment into the nutrient enriching properties of the algal biomass with individual plants in bags and in a controlled environment. This subsequently led to Water Research Commission project K5/1619 (IAPS Algal Biomass and Treated Effluent Utilisation as a Key Strategy in Sustainable and Low-Cost Sanitation).

METHODOLOGY

In order to create a controlled environment, the experiment was undertaken in a horticultural tunnel. The tunnel was set up with a computer controlled drip irrigation system, which delivers 2l/minute per dripper at 1bar of pressure, to ensure that all plants get equal amounts of water. Swiss chard (*Beta vulgaris* L*.cicla)* and Radishes *(Raphanus sativas*) were planted in plant bags in the tunnel. Swiss chard was selected as a leaf crop, which could be harvested repeatedly. Radishes were selected due to its short planting-to-harvest period.

Figure 5 The tunnel at EBRU field station in which crops were grown

The soil used was obtained from a nearby site and was prepared by sifting and mixing so as to ensure consistency throughout all experiments. Eight rows were thus set up for soil amendment trials and three remaining rows for foliar fertilization trials. Approximately 27 repetitions of each experimental condition for each plant were created as follows:

- A control with no treatments
- 1st treatment - Commercial fertilizer
- 2nd treatment - Algal biomass applied as a slurry
- 3rd treatment - A combination of algal biomass and fertilizer

The nitrogen content of the harvested algae was determined and compared to that of commercial fertilizer. All treatments' quantities were then calculated so that each plant received similar quantities of nitrogen. This would enable comparisons of growth rates based on consistent nitrogen. Fertiliser application rates were based on the average recommended fertilisation rates for the two chosen crops at 100g 2:3:2 per square meter [14]. Amount of fertiliser required per planting bag was then calculated using the surface area of a filled bag. This amounted to 1.54g/plant bag of 2:3:2 fertiliser for the fertiliser treatments and 0.77g/plant bag of 2:3:2 fertiliser for the fertiliser-algae treatments. The plants were irrigated using the municipal water at regular intervals, determined initially on a basis of keeping soil moist and subsequently through the use of an irrigation computer programmed to provide small amounts of water at set times during each day. Swiss chard seedlings were bought from a local nursery and planted out. Radishes were planted from seed. 17 days after planting, radish seedlings were thinned out to one radish plant per plant bag (Figure 2). Radishes were harvested after 5 weeks and Swiss chard was harvested after 16 weeks. Both were weighed for fresh (wet) weight, dry weight and ash-free dry weight. Results of the fresh weight are reported here.

Figure 6. Swiss chard and radishes growing in plant bags in pot trials

Various methods were used to develop a foliar feed from the algal biomass. The most significant is the method described by [15], which involved a 'freeze thaw' method including centrifuging and re-suspending to create a clear cell sap. Ultimately, however, running a simple freeze thaw process was seen as most practical and also gave the best results. Foliar feeds were mixed with a dispersant prior to application to leaves to assist with absorption process.

Statistical analysis was done using the Statistica 7 package. One way analyses of variance was conducted on all data to determine if there was a significant difference between treatments. Levene's test was carried out to determine homogeneity of variance between treatments. These were followed by a post-hoc Sheffé test. Normality tests were also done to check if data were normal.

RESULTS AND DISCUSSION

Soil amendments

Fertilised Swiss chard showed the most rapid initial growth but after 5 weeks it appeared that the algae treated Swiss chard has the largest plant growth, this, however was only a visual assessment and the differences were too slight to make deductions at that stage. Harvest results confirmed these initial assessments as shown in figures 7, 3 and 9 and are typical of the trend observed. Fertilizer yields are the highest followed by algae-fertilizer and then algae with the control having the lowest yields. The fact that this trend is consistent through Swiss chard, radishes and multiple harvests shows consistency. This showed that the growth stimulating properties of the algae are not random but rather are attributable to one or more of the biochemical properties of the algae.

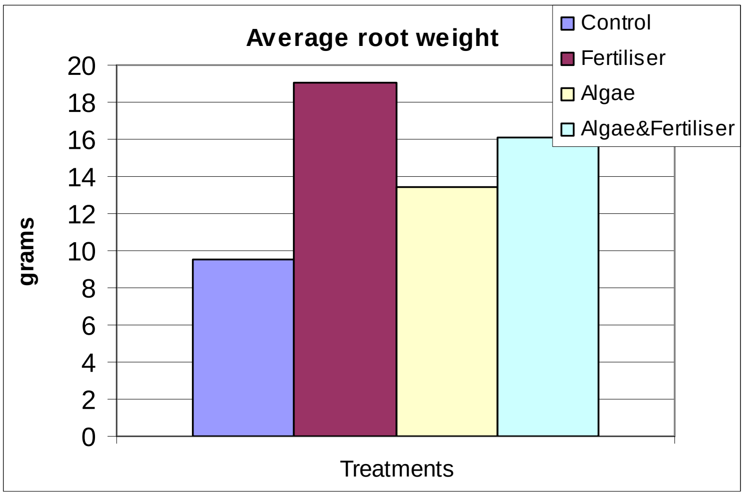

Figure 7 Average root weight results for radish trials at first harvest

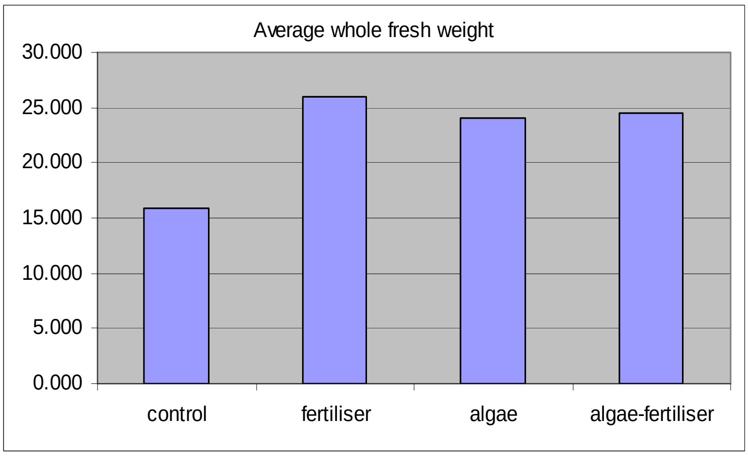

Figure 8 Average whole fresh weight results for radish trials at second harvest

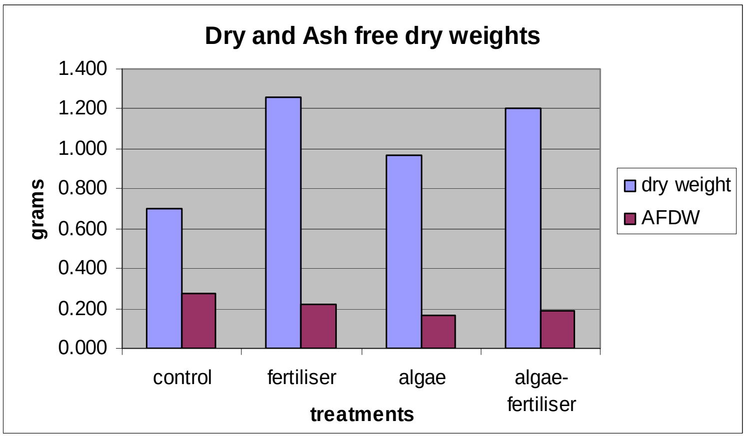

Figure 9 Comparison of ash weights of various different treatments

For both the radishes and swiss chard experiments, the one way ANOVA test showed that there was a significant difference between treatments ($p<001$). The Scheffé post-hoc test revealed that significant differences occurred between the control and all treatments, while there was no significant difference between algae, fertilizer and algae-fertilizer treatments (Table 1). This shows that with statistical significance algae performed as well as commercial fertilizer when applied at the same nitrogen levels. The results shown in figure 3 and 4 also show that there is no significant change in the trend between the first and second harvests. In addition the radish crops were ashed, so as to determine if there is any variation in the inorganic matter component of the treatments. From existing results there appears to be no trend and all plants appear to take up inorganic nutrients similarly.

Table 1 Sheffe test results using Statistica 7

	Control	FERT	ALGAE	AF
Control	/	S	S	S
FERT	S*	/	NS	NS
ALGAE	S	NS[+]	/	NS
AF	S	NS	NS	/

* Significant difference
[+] No significant difference

The results consistently indicate that treating the soil with algal biomass led to higher crop yields than the control. The results in figure 7 and 8 show that commercial fertilizer gave a higher yield than the algae, the next highest being the algae-fertilizer treatment. Though this result shows that the algae may not have as much enrichment quality as the commercial fertilizer it indicates that for a constant nitrogen amendment the algae has a comparable growth stimulus.

Foliar Feed Results

Figure 10 shows the initial results of a foliar feed experiment undertaken. This experiment set out to simply determine whether there was any effect of applying the algal biomass as a foliar feed to the Swiss chard. The results are not conclusive but show that the algal biomass has some effect on the plant yields.

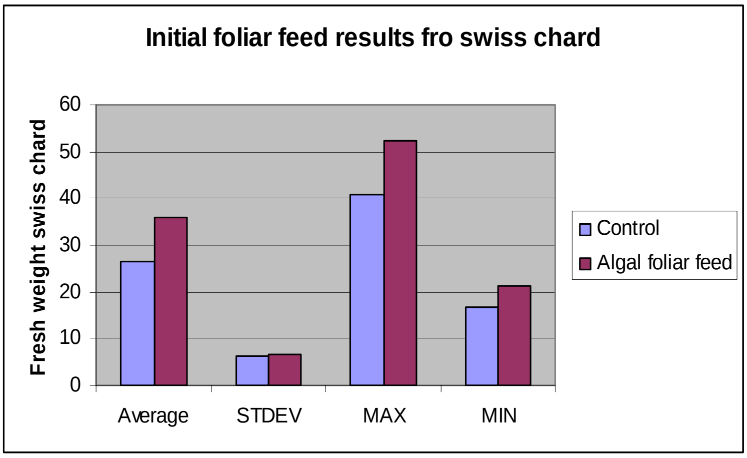

Figure 10 Initial foliar feed results on swiss chard

The results of the foliar feed demonstrate that algae applied as a foliar feed, results in enhanced growth of crops, however, more research is needed to determine the best means of developing foliar feeds from the algal biomass as well as better means of application.

Conclusions and future work

The investigation has set out to determine whether algal biomass produced by the IAPS is able to be used as a fertilizer or soil amendment. In addition the experiment aims to determine whether the algae can be used in a form which can be applied as a foliar fertilizer. In both cases the results show that the harvested algal biomass acts as a growth stimulant. Though the results show that in the methodology used, fertilizer stimulated growth more, the potential exists where the process of water treatment and growth of algal biomass could be optimised to produce a fertilizer which can replace chemical fertilizer. It must also be noted that since the algal biomass could be classified as an organic fertilizer, benefits will exceed purely growth stimulus to include soil organic content and potentially improve microbiological status of the soil. The algal biomass has many advantages over sewage sludge especially with regard to pathogen and heavy metal content. The direction which research into algae as a fertilizer should thus take is to investigate whether the algal biomass has other growth stimulant factors other than purely nutrient content but potentially growth hormones such as gibberellins, cytokinins and auxins. The starting point for this research is to focus on the development of foliar feed type applications of the algae, to compare the developed foliar feeds with commercial foliar feed products and ultimately to undertake research into the commercialisation and optimisation of processes to promote enzymatic components as well as nutrient value of the algae as a fertilizer.

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