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RESEARCH ARTICLE

ON THE PRODUCTION AND THE PURIFYING CAPACITY OF BOURGOU (*ECHINOCHLOA STAGNINA)* BY WASTEWATER STABILZATION PONDS

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ABSTRACT

Bourgou *(Echinochloa stagnina)* production under irrigation with wastewater was carried out on two wastewater processing units.
Channel 1: (B12) bourgou pond fed by anaerobic wastewater,
Channel 2: (B4) of bourgou pond fed by sewage that passed through two hyacinths ponds. The parameters that characterize the organic pollution and nutrients of waste waters and bourgou growth were followed. Weed cutting took place every forty-eight days. The results showed that bourgou growth depends not only on nutrients contributions, therefore the nature of waste water but also plants oxygenation. The bourgou of channel 1 has grown much faster than that channel 2 because wastewater from the channel 1 was richer in nutritive elements (nitrogen-containing organic matter, ortho phosphate ...) than that of channel 2. Wastewater underwent treatment through hyacinth planted filters in both ponds. The yields of fresh and dry bourgou were higher in the (B12) pond than in (B4) pond. Thus they were respectively of 6.11 t / ha and 0.74 t / ha for (B12) against 3.9 t / ha and 0.57 t / ha for (B4) at the first cut on the one part, and the other 18.6 t / ha and 4.03 t / ha for (B12) against 4.13 t / ha and 0.80 t / ha for (B4) at the second cut.

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INTRODUCTION

Currently, promising biological processes such as stabilizing by microalgae and macrophytes have been proposed in some areas. They mainly depend on solar energy, by which aquatic plants living in wastewater, as biosorbents, fix the micro pollutants (Stauber and Florence, 1989; Valdman and Leite, 2000; Zerhouni and Bouya, 2001; Akratos and Tsihrintzis, 2007; De Feo, 2007). This new environmental technology is booming worldwide. Research works have shown that some aquatic plants have significant potential in reducing nutrients (phosphate, nitrates...). The treatment capacity of the combination aquatic plants - bacteria in the sequential treatment of wastewater has been reported by several authors (O'Brien, 1981; Orth and Sapkota, 1988; Debusk *et al*., 1989; Mandi, 1994; Hans, 1994; Tanner, 2001; Sharshar and Haroon, 2009; Stefanakis and Tsihrintzis, 2012) who demonstrated varying degrees of this type of treatment effectiveness. In the Sahel region (Niger, Mali ..) some of these aquatic plants are used as fodder resources.

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Among these fodder production that of bourgou (*Echinochloa stagnina*) is known for its high productivity and high nutritive value (National Research Council, 1996; Nouhou, 1991). This study focuses on the production of bourgou under irrigation, using wastewater. Indeed, wastewater may undergo treatment and be more used for the production of fodder producing species. The aim here is to determine the purifying capacity of bourgou and optimizing its production through the use of wastewater. More primarily, to determine the limiting factors in the production of the specie from wastewater on the one hand and on the other to determine its yield depending on the wastewater treatment plant.

MATERIALS AND METHODS

The study site

The treatment plant of the Abdou Moumouni University Faculty of Sciences in Niamey (Fig.1) treats the University main campus and restaurant wastewater. It offers a possible combination between several ponds to make 3 channels ponds or 6 ponds channels.

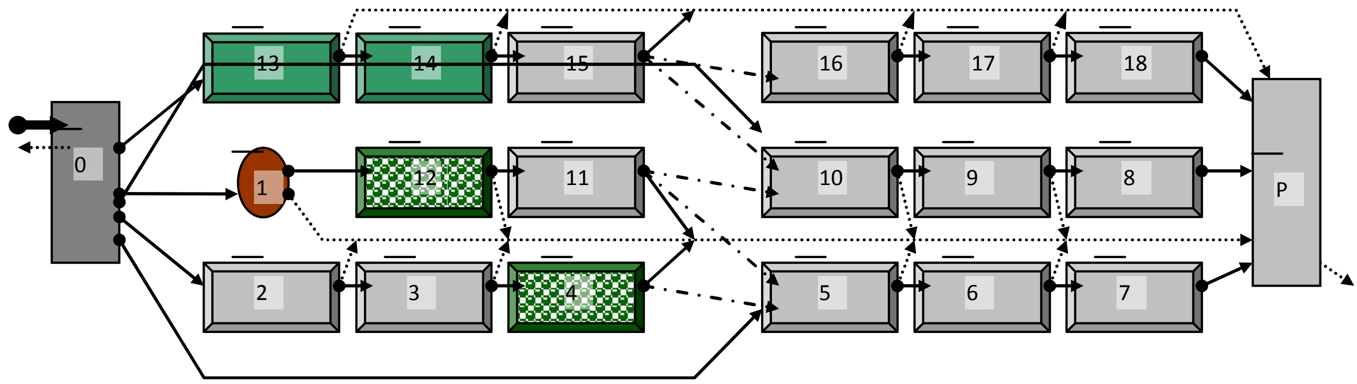

Figure 1. Schematic view of the pilot wastewater treatment plant

LEGENDE:

Pond 0: - An homogenization tank
Pond 1: An anaerobic pit
Ponds from 2 to 18: Ponds planned for the installation of floating or planted microphytes, macrophytes, ponds 12 and 13 can be equipped in high algal output.
Ponds 4 et 12 : Are ponds of planted filter.
Pond P: A water exit collecting pond.
: Alimentation of Channels and passages between ponds in the six Channels configuration.
: By-pass towards pond P.
: Alimentation homogenization pit from wastewater glance.
: A possible connection of Channels 3 ponds in between them.

-A tank of homogenization: pond 0;
-An anaerobic pit of 1 m diameter for a useful depth of 2. 85 Mr. It is an underground reinforced concrete pit with walls some 10 cm thickness: pond 1;
-17 conical ponds of identical shape covered in geo-membrane resistant to UV rays. Surfaces of the water level in these ponds vary from 13. 5 m2 to 15.5 m2 and the depths between 0.7 m and 1 m:numbered ponds from 2 to 18.
An output water exit collecting area: pond P.

Plant Material

The plant material consists of bourgou specie a grass with creeping rhizome. It has a hydrophilic property and grows in semi-arid Sahel zones. Bourgou is known as the best natural pasture because of its high productivity and nutritive value (National Research Council, 1996; Nouhou, 1991). The cuttings used for experimentation have a length of about 15 cm and carry at least one node.

Experimental Protocol

The tests were carried out with the Abdou Moumouni University main campus and restaurant sewage. Two processing units (Fig. 2) were tested:

- Channel 1: purification provided by an anaerobic pond where the water resided 48 hours followed by (B12) bourgou pond.
- Channel 2: purification by two ponds containing water hyacinth. The water resided five days in each pond before entering the (B4) bourgou pond.

Figure 2. Schematic diagrams of the experimental channels

The ponds were fed twice a week to maintain by compensation evaporated water, a constant depth of water of about 10 cm in bourgou ponds. In each bourgou pond, 48 cuttings were transplanted with a mesh size of 40 cm x 40 cm.

Methods of analysis and measurement of parameters

The physicochemical and biochemical parameters

The physico-chemical parameters analyzed were: The pH and temperature. They were measured in situ, at about 10 cm from the water surface, after a slight stirring of the electrode and a stabilization of the display on the meter. The parameters that characterized organic pollution and nutrients were measured once a week on specific samples taken at the outlet of each pond. Most of the analytical methods used (Tab.1) for the analyzes were normalized to the French Standardization Association methods (AFNOR, 1986).

Table 1. References and methods

Parameters	AFNOR References	Materials et methods
pH	NFT 90 008	Multi-parameter Multiline P4 WTW
Temperature		
Flow-type		current meter NAUTILUS C 2
Ammonium (NH4+)	NFT 90 015	Spectrophotometry
Ortho phosphates (PO4)	NFT 90 023	
Nitrites (NO2)	NF T 90-013	

Bourgou growth parameters

A sample of 30 feet in each pond was taken for heights and diameters measurements. Height was measured once a week using a ruler. The measurement was performed on the entire length of the plant including the submerged part. The diameter was measured with a caliper at the first node above the water surface once a week. The weed cutting took place at the end of the forty eightieth days. The cutting was performed at the first node above the water surface, using a chisel. The cut bourgou was bagged and taken to the laboratory, where it was weighed. Samples were then taken to measure the dry matter by drying then desiccation at 105 ° C for 24 h.

RESULTS AND DISCUSSION

A first experiment was conducted from May 5th to July 14th. Bourgou ponds were completely covered with Lemna commonly called duckweed. These duckweeds naturally emerged in the ponds and rapidly spread over the entire surface. The mat thus formed prevents oxygen exchange between the pond water and the atmosphere. This lack of oxygen caused a slowdown in its growth and drying of its leaves. To address these problems, a new experiment is launched during which the lemnas sprouts will be manually and progressively withdrawn from the ponds. The replanting of new nodes was made on August 3rd, the first cut was done on September 20th and the second on November 8th.

Results on nutritive salts from sewage

Throughout the experiment, the pH values of the water ponds have always evolved between 7 and 8.The amount of water introduced in the ponds (B4) and (B12) are respectively 4.166 m^3 and 9.716 m3.

Evolution of ammonium ions (NH4 +)

Ammonium ions concentrations at the entrance of the (B4) bourgou ponds for the hyacinth channel and (B12) for anaerobic channel comprise two zones:

- In the rainy season values at the bourgou ponds entrance, were between 4 mg/l and 13 mg/l for hyacinth channel and between 14 mg/l and 20 mg/l for the anaerobic pathway.
- After the rainy season, the concentrations of ammonium ions vary between 14 mg / l and 23 mg / l to hyacinth channel and between 25 mg/l to 40 mg/l for the anaerobic pathway.
  We note that the bourgou anaerobic pathway receives a greater amount of ammonium than that of the hyacinth. Because the water hyacinth has assimilated some of the minerals.
- In any period, the concentration of ammonium ions in the bourgou ponds output is less than that of the input; this reflects an assimilation of ammonium ions in these ponds.
- Before the first cut, which takes place during the rainy season, 50.5% ammonium ions were eliminated in the pond that received water from hyacinth channel against 94.4% elimination in the pond that received water from the anaerobic pond.
- Between the first and second cut, elimination of ammonium ions in the two ponds was virtually identical: 98.2% for bourgou receiving waters from the hyacinth channel and 98.7% for bourgou that received waters from the anaerobic pathway.

Evolution of Orthophosphates (PO_4^{3-})

During the first stage of experiment, which led to the first cut, the concentrations in orthophosphates at the entrance of the (B12) pond of the anaerobic Channel ranged between 0.5 mg/l and 1.1 mg/l with an average of 0.68 mg/l. At the outlet of the pond, such concentrations range from 0.13 mg/l; 0.81 mg/l with an average of 0.39 mg/l. That is an average of 43% removal rate. Between the first and second cut, the concentrations were higher: At the entrance of the bourgou basin they ranged between 1.2 mg/l and 1.58 mg/l with an average of 1.41 mg/l. At the outlet of the basin, the values are between 0.01 mg/l and 0.11 mg/l with an average of 0.04 mg/l that is a removal rate of 97%. Orthophosphates elimination rate between the first and second cut is greater than before the first cut. Orthophosphates elimination rate in the (B4) basin are of 65.07% for the first phase and 95.94% for the phase between the first cut and second cut. The effluent coming out from the hyacinths ponds to feed the (B4) bourgou pond were less concentrated in orthophosphates than those of (B12) ponds. Indeed, fluctuations in orthophosphates concentration were observed during the residence time in hyacinth ponds. This may be related to the hyacinth which assimilates a large quantity of orthophosphates in relation to residence time.

Evolution of nitrites (NO_2^-)

The assimilation of nitrites in bourgou ponds was extremely low and similar for both channels. Indeed effluents at ponds entrance have concentrations ranging between 0.33 and 0.1 mg/l. At the output concentrations in nitrites were between 0.01 and 0.06 mg/l. Moreover the absence of oxygen in sufficient quantity in the ponds shows that they are not oxidized in nitrate. That is what explains the total absence of nitrates in our ponds.

Results on the growth and yield of bourgou

The assessment of bourgou productivity requires monitoring from transplanting until the cut. The parameters monitored in this study were:

- The survival rate of cuttings;
- The evolution of plant growth;
- Quantity of fresh matter per hectare;
- The weight of dry matter per hectare.

The rate of recovery

Five days after transplantation, the survival rate of cuttings was of 100%. This high rate of recovery was due to the good condition of the cuttings and basins humidity, favorable to the healthy development of bourgou.

Evolution of the height and diameter of bourgou

Growth in length was relatively fast for the first phase, from transplanting to first cut, the height of bourgou was of 157.1 cm ± 18 (STD) for (B12) pond and 139.33 ± 24.22 cm for (B4) pond. Between the first and second cut, the height was

162.13 cm ± 27.6 for (B12) pond and 97.73 ± 40.65 cm for the (B4) pond. The bourgou of (B12) pond has a relatively faster growth than that of (B4) pond with a gap of 64.4 cm in length before the second cutting.

Evolution of the diameter

A quasi linear change in the bourgou main stem diameter in both ponds was observed. The bourgou plants main stem diameter of the (B12) pond was greater than that of the (B4) pond (Tab. 2). This difference can be explained by the richness of mineral elements in the (B12) pond.

Table 2. The different diameters of the stems at the time of the various cuts

	First cut	Second cut
Pond n° 12	9.35 cm ± 1.14	10.47 cm ± 1.15
Pond n° 4	9.03 mm ± 0.7	7.59 mm ± 2.02

Yield of bourgou

Buds increase was low (Tab. 3) to the first cut where the number of buds increased from 7.33 shots ± 2.35 in the (B12) pond and 4.33 shots ± 1.4 in the (B4) pond. Between the first cut and second cut the number of buds in the (B12) pond increased from 19.43 ± 6.01 and 4.66 ± 11 in the (B4) pond.

Table 3. Yield of fresh and dry bourgou matter in ponds based on cuts

Yield of bourgou	Cuts			
	1st cut		2nd cut	
	B4	B12	B4	B12
Number of bud ± standard deviation/foot	4.33 ± 1.4	7.33 ± 2.35	11 ± 4.66	19.43 ± 6.01
Fresh material (t/ha)	3.9	6.11	4.13	18.6
Dry material (t/ha)	0.57	0.74	0.80	4.03

The yields of fresh and dry bourgou matter were higher in the (B12) pond than in the (B4) pond. At the first cut, they were respectively of 6.11 t / ha and 0.74 t / ha in the (B12) pond against 3.9 t / ha and 0.57 t / ha in the (B4) pond. At the second cut the yields obtained were even higher. Fresh stuff yields were of 18.6 t / ha; 4.13 t / ha respectively for (B12) and (B4) and those of the dry matter were of 4.03 t / ha; 0.8 t / ha respectively for (B12) and (B4).

DISCUSSION

A first experiment showed the spontaneous appearance of duckweed in the ponds, which quickly spread, disrupting the growth and development of bourgou. Studies (Wolverton and. McDonald, 1978; Zirschldy and Reed, 1988) have shown that the duckweed has a capacity to proliferate rapidly in urban wastewater, especially heavily loaded. Their presence in large quantities can be a sign of eutrophication. A second experiment is launched, in which duckweeds will be manually removed, as soon as they appear in the ponds. The experimental study has focused on the analysis of certain minerals that play an important role in the growth of the plant. Thus, experience shows that higher there were concentrations of inorganic salts in the (B12) pond than in the (B4) pond. The period from September 20th 2013 to November 8th 2013 where there was no dilution by rainwater, concentrations of NH_4, PO_4 and NO_2 in the (B12) pond were 40 mg/l; 3.52 mg/l; 0.06 mg/ l and in the (B4) pond were respectively of 20.14 mg/l; 1.54 mg/l; 0.04 mg/l. Mineral salts quantity brought during this period were of 379.2 kg/ha NH_4; 32.88 kg/ha PO_4 and 0.56 kg/ha of NO_2 for the (B12) pond and for the (B4) pond the amounts were of 80.67 kg/ha NH_4; 6.16 kg / ha of PO_4 and 0.16 kg / ha of NO_2. These rate levels were due to either protein degradation or to a biological modeling or physico-chemical processes (Florentz *et al*., 1984; Martin, 1987) under conditions of temperature and favorable solar irradiance. The removal of these nutrients in biological treatment systems of wastewater processes are not yet precisely known (Gomez *et al*., 2000; El hafiane *et al*., 2003).The mechanism regularly cited for the removal of these elements is essentially algal biological assimilation dependent on photosynthetic activity (Nouhou, 1991) which determines the growth of algae.

Thus, the (B12) pond being richer in nutrients than the (B4) bourgou pond (B12) has a height greater than that of the (B4) pond. Indeed, the (B12) bourgou pond has an average height of 160 cm in 48 days, an increase of one (1) meter per month while that of the (B4) pond has an average height of 119 cm in 48 days or 0.74 meter per month. The growths obtained as a result of our experimental trials in the (B12) pond (an increase of one meter per month) were consistent with a previous study (Seguin, 1986) conducted in Niger, as part of a PhD thesis in veterinary medicine at Nantes National Veterinary School, which found the same growth, but with a contribution in basal application in wastewater before each planting. The comparative study of the amounts of minerals showed that the amounts of nitrogen and phosphorus measured in our ponds were higher than that of the study with their contribution in manure. Under our experimental conditions bourgou is a fast growing plant, with high productivity of green matter. And yield results of the dry matter differ from one channel to another. The (B12) results provided 4.03 tons of dry matter per hectare in forty-eight days, or 5, 04 tons per hectare in two months. This amount is greater than that found by (Seguin, 1986) with a production of 4.8 tons of dry matter per hectare in two (2) months. The difference in productivity between the (B12) channel and (B4) channel showed that in terms of fresh and dry bourgou yield, it is more advantageous to grow the bourgou plant in (B12) pond. This channel showed a faster growth than the (B4) pond channel.

Conclusion

The bourgou planted filter technique is a simple technique which in addition to the plant productivity, satisfactorily allows treatment of domestic sewage. These results allow us to conclude the possibility of growing bourgou on similar to that of channel 1.This wastewater is certainly richer in nutrients (nitrogen-containing organic matter, orthophosphate ...) but requires regular maintenance vis-à-vis duckweeds. Interest to ensure oxygenation of water for better bourgou growth. The production performance of the channel1 is satisfactory and can overcome the main problem met, that of fodder availability in all seasons.

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